ENERCON SERVICES, INC.	CALCULATION COVER SHEET	CALC. NO. : TXUT-001-FSAR-2.5-CALC-009			
		REV.	3		
		PAGE NO.	1	of	65

Title:	Settlement and Bearing Capacity	Client: MNES
		Project: MITS068

Item	Cover Sheet Items	Yes	No
1	Does this calculation contain any assumptions that require confirmation? (If **YES**, Identify the assumptions)_____		X
2	Does this calculation serve as an "Alternate Calculation"? (If **YES**, Identify the design verified calculation.) **Design Verified Calculation No.**_____		X
3	Does this calculation Supersede an existing Calculation? (If **YES**, identify the superseded calculation.) **Superseded Calculation No.**_____		X

Scope of Revision:

Sections 2.0, 3.0, 5.0, 8.0, and 9.0 are updated to incorporate the revised plant layout and provide additional information. All calculations and appendices except liquefaction (Appendix D) have been revised.

Revision Impact on Results:

None.

Preliminary Calculation	☐	**Final Calculation**	X
Safety-Related	X	**Non-Safety Related**	☐

(Print Name and Sign)

Originator(s): Osman A. El Menchawi	**Date: 09-20-13**
Design Verifier: Kathy Reyes	**Date: 09-20-13**
Approver: Joseph Mancinelli, Project Manager	**Date: 09-20-13**

CALCULATION REVISION STATUS

REVISION	DATE	DESCRIPTION
0	08-04-08	Initial Issuance of Calculation Package.
1	10-23-09	Sections 7.3 and 8.1 are revised to provide additional information [RAI No. 2929 (CP RAI #22), Questions 02.05.04-15 and 02.05.04-17]. Appendices D and E containing additional sample calculations are added. Few editorial corrections are made.
2	08-26-11	Sections 3.1, 5.1, 5.2, 5.4, 5.4.3, 7.3, and 8.1 are updated to include a revised groundwater level and provide additional information.
3	09-20-13	Sections 2.0, 3.0, 5.0, 8.0, and 9.0 have been revised to incorporate the new plant layout and provide additional information. New references have been added to Section 3. Revised Appendices A, B, C, and E.

PAGE REVISION STATUS

PAGE NO.	REVISION	PAGE NO.	REVISION
1-65	3		

APPENDIX REVISION STATUS

APPENDIX NO.	PAGE NO.	REVISION NO.	APPENDIX NO.	PAGE NO.	REVISION NO.
A	1-63	3			
B	1-30	3			
C	1-11	3			
D	1-10	1			
E	1-141	3			

Calculation Design Verification Plan:

1. Apply CSP 3.01 Rev. 6 Section 4.5a (Design Review Method)
2. Review background, methodology, and procedure.
3. Check calculations.
4. Check revised Sections 2.0, 3.0, 5.0, 8.0, and 9.0.
5. Check revised Appendices A, B, C, and E.

(Print Name and Sign)

Approver: Joseph Mancinelli, Project Manager	**Date: 09-20-13**

Calculation Design Verification Summary:

1. Compared documented input with the source reference and checked validity of reference for intended use.
2. Evaluated and verified assumptions to determine that they were based on sound engineering practices and principles.
3. Reviewed background, methodology, and procedure.
4. Checked calculations.
5. Checked revised Sections 2.0, 3.0, 5.0, 8.0, and 9.0.
6. Checked Appendices A, B, C, and E.

Based On The Above Summary, The Calculation Is Determined To Be Acceptable.

(Print Name and Sign)

Design Verifier: Kathy Reyes	**Date: 09-20-13**
Others:	**Date:**

Item	Checklist Items	Yes	No	N/A
1	**Design Inputs** - Were the design inputs correctly selected, referenced (latest revision), consistent with the design basis and incorporated in the calculation?	X		
2	**Assumptions** – Were the assumptions reasonable and adequately described, justified and/or verified, and documented?	X		
3	**Quality Assurance** – Were the appropriate QA classification and requirements assigned to the calculation?	X		
4	**Codes, Standard and Regulatory Requirements** – Were the applicable codes, standards and regulatory requirements, including issue and addenda, properly identified and their requirements satisfied?			X
5	**Construction and Operating Experience** – Have applicable construction and operating experience been considered?			X
6	**Interfaces** – Have the design interface requirements been satisfied, including interactions with other calculations?	X		
7	**Methods** – Was the calculation methodology appropriate and properly applied to satisfy the calculation objective?	X		
8	**Design Outputs** – Was the conclusion of the calculation clearly stated, did it correspond directly with the objectives and are the results reasonable compared to the inputs?	X		
9	**Radiation Exposure** – Has the calculation properly considered radiation exposure to the public and plant personnel?			X
10	**Acceptance Criteria** – Are the acceptance criteria incorporated in the calculation sufficient to allow verification that the design requirements have been satisfactorily accomplished?			X
11	**Computer Software** – Is a computer program or software used, and if so, are the requirements of CSP 3.02 met?	X		

COMMENTS:

(***Print Name and Sign***)	
Design Verifier: Kathy Reyes	**Date:09-20-13**
Others:	**Date:**

COMANCHE PEAK COMBINED OPERATING LICENSE APPLICATION
Calculation Package TXUT-001-FSAR-2.5-CALC-009
SETTLEMENT AND BEARING CAPACITY

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Appendix E R/B Complex Settlement Profile Calculations ....141 Pages

1.0 PURPOSE AND SCOPE

This calculation package summarizes foundation bearing capacity estimates and foundation settlement estimates for the proposed primary seismic category I and II structures of Units 3 and 4 at the Comanche Peak Nuclear Power Plant (CPNPP), for the Combined Operating License Application (COLA). This report summarizes selected laboratory test data and design values and presents recommendations based on the specific plant information available at the time of this report.

2.0 SUMMARY OF RESULTS AND CONCLUSIONS

This document provides discussions and results of settlement and bearing capacity analyses performed for the main seismic category I and II structures within the CPNPP Units 3 and 4. Calculations are provided in the appendices. The following is a brief summary of the results and conclusions:

2.1 Settlement

Results of available and newly obtained geotechnical field and laboratory tests are summarized and used to develop a “Best Estimate (BE)” as well as a “Lower Bound (LB)” modulus model for settlement analysis. Based on the available information regarding structure details, loading, and layout, settlements were estimated using two methods of analysis and the BE and LB models. For all seismic category I and II structure foundations founded on Layer C limestone or on fill concrete which extends from the foundation bottom to the top of solid limestone at a targeted average elevation of 782 ft, the estimated total settlements are generally on the order of 1/2 inch with the differential settlements on the order of 1/3 inch. The structures are expected to experience settlements that are within the project acceptable criterion.

2.2 Bearing Capacity

Bearing capacity for seismic category I and II structures is evaluated using three different failure modes and a conservative set of properties. Results indicate that the ultimate bearing capacity for foundations bearing in Layer C limestone is at least about 146 ksf. The estimated ultimate bearing capacity suggests minimum factors of safety against bearing capacity failure is about 10 for static loading and 7 for seismic loading condition.

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4.0 ASSUMPTIONS

The following is a list of assumptions that were made as part of preparation of this calculation package:

- All foundations for seismic category I and II structures are assumed to be of mat type foundation founded directly on or embedded in competent Layer C limestone or on fill concrete placed over the Layer C Limestone.

- For settlement analysis, all loading conditions were assumed to be flexible uniform loading. A Poisson's ratio of 0.30 was assumed for all rock layers.

5.0 DESIGN INPUT

The following paragraphs provide a summary of the data and information with respect to the plant structures, site grading, and subsurface material properties used in preparing this report.

5.1 General Plant information

The CPNPP structures of each unit consist of the Reactor Building (R/B), Auxiliary Building (A/B), East Power Source Building (EPS/B), and West Power Source Building (WPS/B) all of which share the same foundation mat forming the Reactor Building Complex (R/B Complex). The other structures consist of the Power Source Fuel Storage Vault (PSFSV), Essential Service Water Pipe Tunnel (ESWPT), Ultimate Heat Sink Related Structures (UHSRS), Turbine Building (T/B), and Turbine Generator Pedestal (T/G). There are no seismic category I Duct Banks. The preliminary general plant arrangement showing the layout and plan dimensions of the main structures, foundation loadings, and basement embedment depths have been provided for the proposed CPNPP Units 3 and 4 by Mitsubishi Heavy Industries (MHI) (Ref. 3.1.9 through 3.1.13, 3.1.19, and 3.1.20). All seismic category I and II structures will be founded on or embedded in the competent Layer C limestone which is approximately at an average elevation

of 782 ft or on fill concrete which extends from the foundation bottom to the top of solid limestone at an average elevation of 782 ft. If the foundation bottom elevation is higher than the top of Layer C limestone, the current design requires that all of the materials above the Layer C limestone be removed and replaced with fill concrete.

The following table provides a summary of the pertinent data for the primary seismic category I and II structures within each unit:

Table 5.1-1 Main Seismic Category I & II Structures' Details

Structure	Category	Foundation Size (ft)		Foundation Bottom Elev. (ft)	Static Pressure (ksf)	Seismic Pressure (ksf)
		E-W	N-S			
R/B Complex	I	347	334.58	779.75	13.1	20.9
T/B	II	265.5	342.67	794.83	--	--
T/G	II	62.33	233.42	786.83	--	--
PSFSV	I	98	95	782	4.0	7.6
UHSRS	I	267	160	786	4.9	14.9
ESWPT	I	26 (Tunnel Width)		791.08	4.6	8.5

Based on the center coordinates and dimensions provided in above mentioned references, a relative schematic layout of the main structures within a unit except the ESWPT is shown on Figure 3. The above structures' details, loadings and the layout shown on Figure 3 are used as a basis for all calculations and results provided in this report. The acceptable settlement criterion for the structures is 8.4 inches total and 5.4 inches differential settlement (Ref. 3.1.23). Maximum acceptable differential settlement between buildings is 0.4 inch and the maximum tilt of the R/B complex foundation should also limited to 1/3000 (Ref. 3.1.23).

5.2 Site Grading

Based on the site grading plans provided by MHI (Ref. 3.1.9), the final finish grade for the main plant area will be at elevation 822 feet. The present existing grades vary between El. 830 and 855 feet within the Unit 3 main plant area and between El. 842 and 868 feet within the Unit 4 main plan area. Therefore, approximate cuts range from 8 to 33 feet and 20 to 46 feet for Units 3 and 4 main plant areas, respectively.

5.3 Layer B Shale Removal and Fill Concrete

Table 5.1-1 indicates that foundation bottom elevations for seismic category I and II structures range between elevations 779.75 and 794.83 feet. That range falls within the Layer B material (see Table 5.4.2-1 below). Due to the undesirable potential shrink/swell properties, Layer B shale material below the foundations will be removed to the top of the Layer C limestone rock at a targeted average elevation of 782 feet. Overexcavations below the foundations will be backfilled with concrete to the foundation bottoms.

5.4 Site Conditions and Background Data

5.4.1 Site Exploration

Field exploration and sample collection for the CPNPP Units 3 and 4 project area were performed between November 2006 and April 2007. The field exploration phase included 161 boreholes, ranging from 40 to 550 feet deep, and 3 test pits up to 20 feet deep that were excavated, logged and sampled (Figure 1, Exploration Locations). Logging was performed by Fugro Consultants, Inc. (formerly William Lettis Associates, Inc. (WLA)). Laboratory testing associated with the field work was performed between March 2007 and November 2007 primarily at the Fugro Laboratory in Houston, Texas. Other tests conducted during the field exploration program included the following:

- Downhole pressuremeter testing in 7 boreholes during January, 2007 (Ref. 3.1.6).
- Downhole packer testing in 6 boreholes in February 2007 (Ref. 3.1.2).
- Downhole Suspension P-S logging in 15 boreholes between December 2006 and April 2007 (Ref. 3.1.5).
- Seismic refraction surveys were performed in March 2007 (Ref. 3.1.3).

Evaluations presented herein utilize the results of soil and rock properties described and summarized in the Field Data reports for the various phases of field testing and exploration, including the following Project Reports: Geologic Test Pits (Ref. 3.1.15), Field Packer Test Results (Ref. 3.1.2), Borehole Geophysical Logging (Ref. 3.1.5), and Pressuremeter Test Results (Ref. 3.1.6). This package uses geologic and geotechnical information presented on geologic cross sections prepared by Fugro Consultants, Inc. (formerly WLA). The referenced data reports contain the results of engineering geologic and geotechnical site and laboratory investigation for the proposed CPNPP Units 3 and 4 site locations.

5.4.2 Subsurface Conditions

Subsurface materials within the project site consist of three main geologic formations in descending order: Glen Rose Formation, Twin Mountain Formation, and Mineral Wells Formation. The Glen Rose Formation consists primarily of limestone with interbedded layers of claystone and shale, and is generally overlain by a layer of fill or residual soils, which varies in thickness from a few feet to a few tens of feet. Boring log and geophysical data further refined the subsurface into twelve major stratigraphic layers labeled A through I. Figure 2 shows a typical geologic cross section for the main site of Units 3 and 4. A summary of the refined stratigraphic layers for the site is provided in Table 5.4.2-1. More detailed information and data regarding the project subsurface materials and stratigraphic layers are provided in References 3.1.16 and 3.1.18.

Residual soil material types ranged from sand and gravel with varying amounts of fines, to silt and sandy lean clay. Some areas of the site (northeast of Unit 4 and east to southeast of Unit 3) contain areas of randomly placed, uncompacted fill. These fill materials are located in areas of previous topographic lows and range in thickness from 5 to about 70 feet deep.

Table 5.4.2-1 Stratigraphic Layer Depth Profile

Formation	Stratigraphic Layers	Primary Lithology	Top of Layer Ave. Elevation (ft)	Average Thickness (ft)
Glen Rose	A	Limestone	834	35
	B1	Shale	798	8
	B2	Shale with Limestone interbeds	790	8
	C	Limestone	782	65
	D	Shale	717	4
	E1	Limestone	714	23
	E2	Limestone	690	35
	E3	Limestone	656	33
Twin Mountain	F	Limestone with Shale and Sand interbeds	622	30
	G	Sandstone	593	80
	H	Shale	513	63
	I	Sandstone	451	67
Mineral Wells	MW	Shale with Sandstone and Limestone interbeds	388	--

5.4.3 Groundwater Conditions

Information gleaned from the FSAR for Units 1 and 2 (Ref. 3.1.8) suggest that static water levels observed within the borings and monitoring wells completed within the Glen Rose Formation ranged between El. 749 and 830 feet. However, the FSAR concluded that the Glen Rose Formation is an essentially impermeable formation and that the piezometric levels measured in the Glen Rose Formation are associated with perched water in the upper zone of the Glen Rose Formation in the immediate area of each piezometer. The single piezometer completed in the Twin Mountain Formation indicated a piezometric water level at El. 670 feet. The Units 1 and 2 FSAR concludes that the groundwater at the site is not expected to rise above El. 775 feet (Probable Maximum Flood level). Historical groundwater levels around the plant site from a few observation wells in Somervell County suggest that the permanent groundwater levels range between about elevation 600 and 760 feet.

During the field investigation for Units 3 and 4, a number of monitoring wells were installed within the Glen Rose Formations to depths of about 15 to 95 feet below the existing ground surface. Preliminary results from the monitoring suggest piezometric levels ranging between about El. 775 to 858 feet, although some wells were reported to be dry. In general, the subsurface soils and much of the rocks especially the Glen Rose Formation are considered relatively impermeable. All observed piezometric levels at the site are considered to be localized perched water in the upper zone of the Glen Rose Formation and are possibly attributed to surface run-off and not a true indication of the site groundwater level. The results of the Packer tests performed during the site investigation also suggest that the Glen Rose Formation is fairly tight with little potential for "significant" seepage and groundwater.

According to the USGS, the Conservation Pool Elevation of the Squaw Creek Reservoir is 775 feet. Based on the information collected by the USGS gauging station located on Squaw Creek Reservoir during the period of October 1, 2000 to June 4, 2007, the maximum reservoir elevation was recorded at 777.97 feet on June 9, 2004, and the minimum reservoir elevation was recorded at 772.96 feet on April 28 and 29, 2005 (Ref. 3.1.1).

Two areas of uncontrolled fill are present within and in the vicinity of Units 3 and 4 areas and are known to have hydraulic connectivity with Squaw Creek Reservoir. Those fill areas are located east to southeast of Unit 3 and northeast of Unit 4. The bottom of fill in the area between Units 3 and 4 is expected to be above the level of anticipated excavation (~ El. 782 ft) as well as the Squaw Creek Reservoir pool elevation (~ El. 775 ft). The fill area to the east and southeast of Unit 3, which is generally located outside of the limits of the main plant area becomes deeper in a northeasterly direction and extends to levels below the Squaw Creek Reservoir Pool Elevation of 775 feet.

Based on theoretical maximum precipitation events, the maximum groundwater level calculated in Ref. 3.1.25 around the nuclear island is 794.94 ft msl. The areas of Units 3 and 4 within the Essential Service Water Pipe Tunnel (ESWPT) is essentially a closed basin which had not been included in the model area in Ref. 3.1.25. The pipe tunnels enclose this area, with the tops of individual segments of the pipe tunnels ranging from 804 ft msl to 810 ft msl. Because this is a closed area, the water level within this area can theoretically reach a maximum of 804 ft msl; once it has reached this elevation, the water will drain outward across those portions of the pipe tunnel having tops at that elevation. As a result, a conservative potential maximum groundwater level within the engineered fill of 804 feet will be used in the current set of calculations.

5.5 Geotechnical Laboratory Test Data

5.5.1 Material Index Properties

Laboratory testing was performed to assess engineering properties appropriate for the level of analysis and is discussed herein. Generally, as shown on Figure 2, subsurface conditions consist of fairly shallow thicknesses of soil underlain by alternating layers of limestone, shale, and sandstone. Unit weight and other index properties are described in the Laboratory Data Report (Ref. 3.1.4). Results of the Laboratory Index test results are presented on Figures 4 through 10, and summarized in Table 5.5.1-1:

Table 5.5.1-1 Summary of Index Laboratory Test Result Ranges

Parameter	Material			
	Soil	Shale	Limestone	Sandstone
Total Unit Weight, pcf	_	118-169	136-165	124-147
Total Dry Unit Weight, pcf	_	99-147	119-160	105-134
Water Content, %	_	5-22	1-19	8-19
Carbonate Content, %	_	3-72	74-100	0-7
Organic Content, %	2-3	_	_	_
Specific Gravity	_	2.74-2.78	2.69-2.72	2.65

Slake Durability, %	--	0-83	91-98	_
Liquid Limit Plasticity Index	25-60 9-43	27-71 14-48	–	–

The results of the unit weight tests, the number of tests performed, mean, and the assigned typical values are also summarized in Table 5.5.1-2 with respect to the assigned stratigraphic layers. The representative values of unit weight were selected based on the laboratory test results, material lithology, and engineering judgment, and are considered to be reasonably representative values for design.

Table 5.5.1-2 Rock Material Unit Weights

Layers	Primary Lithology	No. of Tests	Total Unit Weight, pcf		Assigned Typical Total Unit Weight, pcf
			Range	Average	
A	Limestone	40	119-165	149	145
B1	Shale	46	118-163	140	135
B2	Shale with Limestone interbeds				135
C	Limestone	62	135-163	155	155
D	Shale	7	131-169	147	135
E1	Limestone	24	134-161	151	155
E2	Limestone				155
E3	Limestone				150
F	Limestone with Shale and Sand interbeds	4	124-133	130	130
G	Sandstone	8	124-141	134	135
H	Shale	6	138-149	144	140
I	Sandstone	2	154-155	155	145
MW	Shale with Sandstone and Limestone interbeds	--	--	--	150

5.5.2 Strength Properties

Rock strength was assessed using point load tests (both axial and diametral), unconfined compression tests, and triaxial tests (consolidated undrained tests without pore pressure measurements). Compressive strength data are plotted versus elevation on Figure 11. Figures 12 and 13 present a cumulative probability distribution of unconfined compressive strength of limestone and shale that also includes the available data from Units 1 and 2. The combined data set for limestone seems to indicate a normal distribution, whereas the shale data set seems to correlate better with a log normal distribution. Table 5.5.2-1 summarizes strength test results ranges for shale and limestone samples.

Table 5.5.2-1 Summary of Strength Test Results

Strength Type	Material		
	Shale	Limestone	Sandstone
Unconfined Compressive Strength, tsf	13-104	73-812	10
Consolidated-Undrained Compressive Strength (w/o pp), tsf	10-82	126-587	124
Unconsolidated-Undrained Compression Strength, tsf	4-41	204-566	50
Point Load Strength (axial), tsf Point Load Strength (diametral), tsf	--	10-742 14-523	7-136 35

The results of the strength tests, the number of tests performed, mean and the selected representative values are also summarized in Table 5.5.2-2 with respect to the assigned stratigraphic layers. The assigned values of unconfined compression were selected based on the laboratory test results, material lithology, and engineering judgment. These are considered to be reasonably representative values.

Table 5.5.2-2 Unconfined Compressive Strength

Layers	Primary Lithology	Unconfined Compression, tsf			Point Load Test (axial), tsf			Assigned Representative UC Strength, tsf
		No.	Range	Average	No.	Range	Average	
A	Limestone	11	92 - 513	281	11	133 - 645	324	200
B1	Shale	7	13 - 790	291	1	455	-	50
B2	Shale with Limestone interbeds							
C	Limestone	39	73 - 812	290	22	10 - 742	264	250
D	Shale	-	-	-	-	-	-	50
E1	Limestone	6	104 - 311	251	6	73 - 605	260	250
E2	Limestone							
E3	Limestone							
F	Limestone with Shale and Sand interbeds	-	-	-	-	-	-	100
G	Sandstone	1	10	-	1	7	-	200
H	Shale	-	-	-	1	136	-	200
I	Sandstone	-	-	-	-	-	-	200
MW	Shale with Sandstone and Limestone interbeds	-	-	-	-	-	-	300

5.6 Geotechnical In situ Field Test Data

5.6.1 In situ Shear & Compression Wave Velocity Data

In situ shear (S) and compression (P) wave velocity measurements were performed by Suspension P-S logging method in 15 boreholes by GeoVision Geophysical Services. Details of the field work and results are discussed in GeoVision Report (Ref. 3.1.5). The results were further analyzed and reduced by WLA, and integrated velocity profiles were developed for the project site, which are presented in the Project Calculation Package No. TXUT-001-FSAR-2.5-CALC-003 (Ref. 3.1.17). Figure 14 provides a composite summary of the measured S- and P-wave velocities for all 15 boreholes as well as the respective mean values for the integrated site model.

5.6.2 In Situ Pressuremeter Tests

In situ pressuremeter testing was conducted in seven boreholes by Hughes Insitu Engineering. Details of the field work and results are discussed in Hughes Report (Ref. 3.1.6). Figure 15 provides a summary of the pressuremeter tests results.

5.6.3 In Situ Packer Tests

In situ packer tests were performed in six boreholes by Fugro. Details of the field work and results are discussed in the Project Report TXU-001-PR-003 (Ref. 3.1.2). Figure 16 provides a summary of the packer tests results.

5.6.4 In Situ Rock Quality Designation

In situ Rock Quality Designation (RQD) of the rock core samples was measured by Fugro Consultants, Inc. (formerly WLA) field geologists during the field exploration activities. The results of the measured RQD values are shown on the individual logs within the Boring Log Data Report prepared by Fugro (formerly) WLA (Ref. 3.1.14). Figure 17 provides a summary of the measured RQD values for all borings.

6.0 GEOTECHNICAL DESIGN PROPERTIES

6.1 Characterization of Rock Deformation Properties

A variety of laboratory and field test methods were used to describe the deformation characteristics for rock materials. Deformation characteristics of the subsurface rock materials were developed using two approaches as presented below:

- Best Estimate for Rock Mass Modulus: Subsurface rock deformation characteristics were estimated using in situ shear (S) wave velocities measured during the downhole suspension logging. Because the downhole velocity measurements reflect the local influence of rock discontinuities and material variations, the resulting calculated modulus value are considered more indicative of the rock mass conditions. However, due to the low strain nature of the shear wave velocity, the calculated modulus is an upper bound case when used for settlement calculations. The low strain modulus values were

reduced to reflect the relative higher strain levels anticipated for the fully loaded foundations. The modulus model developed based on this procedure is considered to represent the Best Estimate (BE) model for use in settlement analysis.

- Lower Bound for Rock Mass Modulus: Subsurface rock deformation characteristics also were estimated using the results of stress-strain measurements in the laboratory on intact core samples, and in situ tests in boreholes using a pressuremeter. Because the individual core samples and pressuremeter tests do not consider the discontinuities or material variations, the Rock Mass Rating (RMR) System (Ref. 3.2.2), and Geological Strength Index (GSI) System (Refs. 3.2.6 & 3.2.4) were used to incorporate the effects of discontinuities and material variations and assess the overall rock mass deformation characteristics. The modulus model developed based on this procedure is expected to produce a conservative Lower Bound (LB) modulus model for use in settlement analysis.

The following sections provide details and procedures used to develop the above two rock deformation models.

6.1.1 Best Estimate for Rock Mass Modulus

Measured values of shear and compression wave velocities provide an indirect measurement of the low-strain in situ rock modulus. In situ rock modulus is estimated from the shear wave velocities using the following relationships:

$$G_{\max} = \frac{\gamma}{g} \cdot V_s^{\,2}$$

where:

$G_{\max}$ = Low Strain Shear Modulus (psf)
V_s = Shear Wave Velocity (fps)
γ = Total Unit Weight (pcf)
g = Gravitational Acceleration Constant (32.2 ft/s^2).

Poisson's ratio (ν) is determined as follows:

$$\nu = \frac{V_p^{\,2} - 2\mathrm{V}_s^{\,2}}{2 \cdot \left(\mathrm{V}_p^{\,2} - V_s^{\,2}\right)}$$

where:

ν = Poisson's ratio
V_p = Compression Wave Velocity (fps).

From the above information, the Modulus of Elasticity or Young's Modulus (E) is determined from:

$$E_{\max} = 2G \cdot (1+\nu)$$

$$E = E_{\max}(RF)$$

where:

$E_{\max}$ = Low Strain Modulus of Elasticity or Young's Modulus
E = Strain Adjusted Modulus of Elasticity or Young's Modulus
RF = Reduction Factor for Modulus Strain Adjustment

Results of the integrated mean velocity profiles along with the Poisson's ratio values are discussed and presented in the Project Calculation Package No. TXUT-001-FSAR-2.5-CALC-003 (Ref. 3.1.17). The low strain modulus (E_{max}) values were empirically reduced in order to develop a modulus model that is more compatible with the level of anticipated settlement. Reduction curves used for this adjustment are shown on Figure 18 (Ref. 3.1.7). An iterative process was used between strain, calculated modulus and settlement in order to select the appropriate reduction factor for each layer. The following relation between the axial and shear strain was used for utilizing Figure 18:

$$\gamma_{\max} = (1+\nu)\varepsilon$$

where:

$\gamma_{\max}$ = Maximum Shear Strain
ε = Axial Strain
ν = Poisson's ratio

A summary of the velocity data, Poisson's ratio values, and the calculated Young's Modulus values versus depth and stratigraphic layers are summarized in the following Table 6.1.1-1:

Table 6.1.1-1 Summary of Rock Velocities, Poisson's Ratio, and Young's Modulus

Layers	Mean V_s, fps	Mean V_p, fps	Poisson's Ratio	Total Unit Weight, pcf	Shear Modulus (G_{max}), tsf	Young's Modulus (E_{max}), tsf	Strain Reduction Factor (RF)	Strain Adjusted E_{max} (E), tsf
A	3,548	8,788	0.40	145	28,343	79,361	0.98	77,774
B1	2,609	6,736	0.41	135	14,269	40,239	0.55	22,131
B2	2,716	7,640	0.43	135	15,463	44,226	0.55	24,324
C	5,685	11,324	0.33	155	77,787	206,913	0.98	202,775
D	3,019	8,312	0.42	135	19,106	54,2612	0.55	29,844
E1	4,943	10,486	0.36	155	58,807	159,954	0.98	156,755
E2	6,880	13,164	0.31	155	113,926	298,486	0.98	292,516
E3	4,042	9,255	0.38	150	38,054	105,029	0.98	102,928
F	3,061	7,927	0.41	130	18,914	53,338	0.68	36,270
G	3,290	7,593	0.38	135	22,690	62,625	0.88	55,110
H	3,429	8,188	0.39	140	25,561	71,060	0.83	58,979
I	3,092	7,686	0.40	145	21,526	60,273	0.92	55,451
MW	5,546	10,627	0.32	150	71,642	189,134	1.00	189,134

A summary plot of the mean low strain Young's modulus (E_{max}) and the strain adjusted Young's modulus (E) values versus stratigraphic layer and the elevation is presented on Figure 19.

6.1.2 Lower Bound for Rock Mass Modulus

6.1.2.1 Rock Mass Quality

As part of the exploration conducted by Fugro for the Units 3 and 4 COLA, rock coring and logging were performed onsite, with observations of rock quality that included discontinuities and jointing information recorded on the boring logs. Rock mass quality information was recorded in photographs and noted on the core logs. Rock Quality Designation (RQD) values are plotted versus elevation on Figure 17 along with a line representing the average. RQD values ranged from 0 to 100 percent, with a statistical average value of 96 percent. RQD is one of the input parameters used to determine the Rock Mass Rating (RMR). Average RQD values selected for stratigraphic layers ranged from 80 to 99 percent depending on the layer.

6.1.2.2 Rock Mass Classification using RMR and GSI

Bieniawski published details for the Rock Mass Rating (RMR) System which is also referenced as the Geomechanics Classification System (Ref. 3.2.1). The RMR method is meant to account for large scale discontinuities that would not be represented by laboratory testing of rock samples. It is a geomechanics classification that can be applied to estimate the in situ modulus of deformation and behavior of a rock mass based on empirical data and experience.

The GSI system (Refs. 3.2.3 and 3.2.5) provides a system for estimating the rock mass strength of different geological conditions as an alternative to the RMR Classification. The GSI is in part specific to the rock type. The strength of a jointed rock mass depends on the properties of the intact rock pieces, discontinuities, spacing and orientation, and filling.

For the CPNPP site, both the RMR and the GSI systems were used to estimate the rock mass modulus.

The RMR was evaluated for each stratigraphic layer, in accordance with the U.S. Army Corps of Engineers Rock Foundations Manual (Ref. 3.2.12), and most recently updated by Hoek (Ref. 3.2.2).

The following six (6) parameters are used to classify a rock mass using the RMR system:

- Uniaxial Compressive Strength of the intact rock
- Rock Quality Designation (RQD)
- Spacing of discontinuities
- Condition of discontinuities surfaces
- Groundwater conditions
- Orientation of discontinuities relative to the engineered structure

The rock is described, based on observations and tests, and points are assigned for the condition of the rock. All rock description category points are tallied and the resulting number is the RMR, ranging potentially from 0 to 100. Parameters are used to provide an overall rating, as indicated on Figure 20 Rock Mass Rating System and Project Parameters.

Figure 20 presents the ratings for each stratigraphic layer, along with the resulting RMR, which ranges from 63 (clayshale) to 89 (sandstone). An average RMR value of 70 for the rock mass as a whole was selected as representative for the bearing strata (Layer C) and deeper.

The GSI is a system of rock-mass characterization based on visually assessing the geological character of the rock material and for the prediction of rock mass strength and deformability. The lithology, structure and condition of discontinuity surfaces in the rock mass are estimated from visual examinations of the rock mass exposed in outcrops, in surface excavations and borehole cores (Ref. 3.2.7). The GSI combines rock mass blockiness discontinuity conditions. The system for estimating the GSI from the geological observations is presented in Figure 21; GSI Chart.

The GSI classification was originally introduced because Bieniawski's RMR classification was difficult to apply to very poor quality rock masses. For better quality rock masses, the value of GSI can also be estimated directly from the RMR classification. The GSI can be estimated directly from the 1989 version of Bieniawski's Rock Mass Rating (RMR_{89}), where RMR has the groundwater rating set to 15 and the adjustment for joint orientation set to zero. In this case the GSI can be calculated from:

$$GSI = RMR_{89} - 5$$

Within the CPNPP site, GSI values were developed for each stratigraphic layer that was interpreted by WLA based on the RMR classification and the relationship between RMR and GSI, as described above. GSI Values ranged from 58 to 84. An average GSI value of 68 was selected as representative of material within and below the foundation bearing zone.

Selected RMR or GSI values are entered into a set of empirically developed equations to estimate the rock mass strength and deformability properties by means of the Hoek-Brown criterion (Refs. 3.2.3 and 3.2.5). The indices are used in conjunction with appropriate values for the unconfined compressive strength of the intact rock (σ_{ci}) and the petrographic constant (m_i) to calculate the mechanical properties of a rock mass (compressive strength of the rock mass - σ_{cm}) and its deformation modulus, E.

6.1.2.3 Rock Mass Modulus Estimates

Laboratory test results from individual rock samples and the RMR and GSI values were used to estimate the deformation modulus of the rock mass by using empirical equations summarized by Hoek and Diederichs (Ref. 3.2.4). For the CPNPP Project four (4) empirical approaches were selected to define the Rock Mass Modulus range. The following table summarizes these approaches:

Table 6.1.2.3-1 Rock Mass Modulus Empirical Relationships

Empirical Relation	Reference
$E_{rm} = \frac{E_i}{100}\left(0.0028RMR^2 + 0.9e^{\frac{RMR}{22.82}}\right)$	Nicholson and Bieniawski, 1990
$E_{rm} = \frac{1}{2}E_i\left(1-\cos\left(\pi\frac{RMR}{100}\right)\right)$	Mitri et al., 1994
$E_{rm} = E_i\left(s^a\right)^{0.4}$ $s = e^{\frac{(GSI-100)}{9}}$ $\quad a = \frac{1}{2}+\frac{1}{6}\left(e^{-\frac{GSI}{15}} - e^{-\frac{20}{3}}\right)$	Sonmez et al., 2004
$E_{rm} = E_i\left(0.02 + \frac{1-(D/2)}{1+e^{\left(\frac{(60+15D-GSI)}{11}\right)}}\right)$	Hoek & Diederichs, 2006

Where:

E_{rm} = Rock Mass Modulus

E_i = Intact Modulus = MR (σ_{ci})

σ_{ci} = Uniaxial Compression Strength

MR = Modulus Ratio

Uniaxial compression strength values were taken from Table 5.5.2-2. The modulus ratio values were selected based on the guideline recommendations by Hoek and Diederichs (Ref. 3.2.4), and are shown in Table 6.1.2.3-2:

Table 6.1.2.3-2 Summary of Rock Modulus Ratio Values

Layers	Primary Lithology	Modulus Ratio (MR)
A	Limestone	350
B1	Shale	250
B2	Shale with Limestone interbeds	250
C	Limestone	400
D	Shale	250
E1	Limestone	400
E2	Limestone	400
E3	Limestone	400
F	Limestone with Shale and Sand interbeds	350
G	Sandstone	300
H	Shale	250
I	Sandstone	300
MW	Shale with Sandstone and Limestone interbeds	400

The estimated range of the Rock Mass Modulus (E_{rm}) values for each of the stratigraphic layers, based on the above four correlations and their average value, are presented on Figure 22. Modulus values from the field pressuremeter tests and the laboratory unconfined compression tests are also shown on Figure 22 for comparison. The average estimated rock mass modulus compares well with the lower bound of the intact modulus values from the laboratory or field measurements and is considered to be a reasonable representation of deformation characteristics of the site rock mass profile.

Estimated rock mass properties, including the RMR and GSI ratings, cohesion, friction angle, and Young's modulus for the individual stratigraphic layers, are summarized in Table 6.1.2.3-3.

Table 6.1.2.3-3 Summary of Rock Mass Properties

Layers	Total Unit Weight, pcf	RMR	GSI	Rock Mass Cohesion, tsf	Rock Mass Friction Angle, degrees	Rock Mass Young's Modulus (E_{rm}), tsf
A	145	76	71	3.1 – 4.2	35 - 45	45,754
B1	135	63	58	3.1 – 4.2	35 - 45	5,825
B2	135	63	58	3.1 – 4.2	35 - 45	5,825
C	155	79	74	3.1 – 4.2	35 - 45	69,606
D	135	63	58	3.1 – 4.2	35 - 45	5,825
E1	155	79	74	3.1 – 4.2	35 - 45	69,606
E2	155	79	74	3.1 – 4.2	35 - 45	69,606
E3	150	79	74	3.1 – 4.2	35 - 45	69,606
F	130	75	70	3.1 – 4.2	35 - 45	22,377
G	135	84	79	> 4.2	> 45	45,933
H	140	83	78	> 4.2	> 45	37,587
I	145	83	78	> 4.2	> 45	45,105
MW	150	89	84	> 4.2	> 45	100,149

7.0 ANALYTICAL METHODOLOGY

7.1 Settlement

Rebound deformation due to foundation excavations and settlement from foundation loading are anticipated to be elastic in nature. Rebound and settlements were estimated by elastic theory. The following two methods were used to compute the estimated settlement for the major structures within the CPNPP Units 3 and 4 area:

7.1.1 Non-layered Method

The non-layered method considers the subsurface rock layers supporting the foundations as a homogeneous elastic half-space medium with a uniformly loaded rectangular area. The formulas by Schleicher (1926) are used to calculate the settlement of any location beneath a loaded rectangle foundation (Equation 5-2, Ref. 3.2.9).

$$\delta_d(x,y) = C_s q B \left(\frac{1-\nu^2}{E} \right)$$

The parameter C_s is a geometric factor that accounts for the shape of the rectangle and the position of the point for which the settlement is being calculated. The formula for calculating C_s is as follows (Equation 5-3, Ref. 3.2.9):

$$C_s = \frac{1}{2\pi}(C_1 + C_2 + C_3 + C_4)$$

$$C_1 = B_1 \ln \frac{\sqrt{A_1^2 + B_1^2} + A_1}{\sqrt{A_2^2 + B_1^2} - A_2}$$

$$C_2 = B_2 \ln \frac{\sqrt{A_1^2 + B_2^2} + A_1}{\sqrt{A_2^2 + B_2^2} - A_2}$$

$$C_3 = A_1 \ln \frac{\sqrt{A_1^2 + B_1^2} + B_1}{\sqrt{A_1^2 + B_2^2} - B_2}$$

$$C_4 = A_2 \ln \frac{\sqrt{A_2^2 + B_1^2} + B_1}{\sqrt{A_2^2 + B_2^2} - B_2}$$

$$A_1 = 1 - \frac{2x}{B}$$

$$A_2 = 1 + \frac{2x}{B}$$

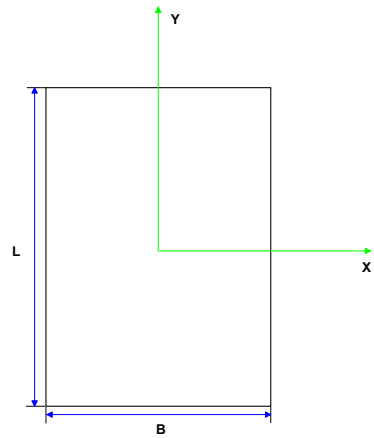
$$B_1 = \frac{L}{B} - \frac{2y}{B}$$

$$B_2 = \frac{L}{B} + \frac{2y}{B}$$

where:

$\delta_d(x, y)$	=	Settlement of the point with coordinates of (x, y)
q	=	Uniform load intensity
C_s	=	Geometric factor
B	=	Width of the loaded area
L	=	Length of the loaded area
ν	=	Poisson's ratio
E	=	Average Elastic or Young's modulus
A_1, A_2	=	Factors to be calculated based on the above formulas and then inserted into the formulas for C_1 through C_4
B_1, B_2	=	Factors to be calculated based on the above formulas and then inserted into the formulas for C_1 through C_4
$C_1 - C_4$	=	Factors to be calculated based on the above formulas and then inserted into the main formula for C_s

x, y = x and y coordinates of the point (see figure below)



The average elastic modulus for the half-space was calculated using a weighted average modulus approach, as indicated by the following relationships (Equation 5.1, Ref. 3.2.12):

$$E_{avg} = \frac{\sum_{i=1}^{n}\left(E_i \Big/ \sum_{j=1}^{i} h_j\right)}{\sum_{i=1}^{n}\left(1 \Big/ \sum_{j=1}^{i} h_j\right)}$$

Where:

E_{avg} = Weighted average modulus

E_i = Elastic modulus of each layer

h_j = Thickness of each layer

n = Number of layers

7.1.2 Layered Method

The layered method is similar to the non-layered method, but considers the subsurface rock materials supporting the foundations to be a layered system. The stress increase with depth caused by a rectangular uniform surface load is computed using a stress distribution theory. Superposition of rectangular areas covering the loaded surfaces is used for the cases where the stress calculation point is not located directly under the corner of a given loaded area or when there is more than one loaded area. The strain of each layer is calculated by dividing the stress increment by the layer modulus and then the strain multiplied by the layer thickness to provide the layer compression or settlement. The computed settlement values of all layers are summed to provide the total settlement values shown below:

$$\delta = \sum_{i=1}^{n} \delta_i = \sum_{i=1}^{n} \varepsilon_i h_i = \sum_{i=1}^{n} \frac{\Delta\sigma_i}{E_i^e} h_i$$

Where:

δ = Total Settlement

δ_i = Settlement of each layer

ε_i = Strain in each layer

h_i = Thickness of each layer

$\Delta\sigma_i$ = Stress increment in each layer due to loading

E_i^e = Equivalent elastic modulus of each layer

In the above formula for the equivalent elastic modulus (E_i^e), values of Young's modulus (E_i), plane strain modulus ($E_i^{'}$), or constrained modulus (M_i), as defined below, may be used, depending on the boundary conditions or location of the settlement point.

$$E_i^{'} = \frac{E_i}{1-\nu^2}$$

$$M_i = E_i\left[\frac{1-\nu_i}{(1+\nu_i)(1-2\nu_i)}\right]$$

where:

E_i = Young's modulus of each layer

$E_i^{'}$ = Plane strain modulus of each layer

M_i = Constrained modulus of each layer

ν_i = Poisson's ratio of each layer

For the cases where the foundation dimensions are relatively large, the lateral deformation at points below the center of the foundation is considered fully constrained and use of the constrained modulus is more appropriate. On the other hand, in the cases of small foundations and areas near corners or edges of large foundations, the lateral deformations will not be constrained and the Young's modulus is more appropriate for settlement computations. For the settlement calculations provided in this report, the plane strain modulus, which considers the strain to be constrained in only one direction, was adopted. The plane strain modulus, which is lower than the constrained modulus and slightly higher than the Young's modulus, was judged to be a reasonable selection and appropriate for representing all points below loaded areas for both large and small size foundations.

There are several elastic solutions that can be used to calculate stress distribution, such as Boussinesq, Mindlin, and Westergaard. There is no definitive proof that either of these solutions is more accurate than the other for the soil or rock applications (Ref. 3.2.10). Among the available solutions, the Boussinesq solution has been most widely used for geotechnical applications. It has also been found that settlements obtained through use of the Boussinesq equation are, in the great majority of cases, larger than the observed settlements. We conservatively selected the Boussinesq solution for computing the stresses distribution under the loaded areas for the settlement calculations presented in this report. The Boussinesq

equation for calculating vertical stress increment under a corner of a rectangular uniformly distributed flexible loaded area is expressed as follows (Ref. 3.2.11):

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

$$m = \frac{L}{Z}$$

$$n = \frac{B}{Z}$$

where:

σ_z	=	Stress increment at a depth z
q	=	Uniform load intensity as surface
B	=	Width of the loaded area
L	=	Length of the loaded area
Z	=	Distance below the loaded area
m,n	=	Ratio of loaded area width or length to depth

The vertical stress induced at other locations than the corner or by more than one foundation can be obtained by superposition approach.

7.1.3 Rock Mass Elastic Deformation Model

As described previously, two models were developed to independently represent the best estimate and a lower bound model for the rock mass elastic deformation modulus. The first model, described in Section 6.1.1, was developed based on the in situ shear wave velocity data, and is generally considered to best represent the actual deformation behavior of the subsurface rock mass. The second model, described in Section 6.1.2, was developed based on the laboratory test results for the core samples and the available empirical correlations. This model is considered conservative and may be viewed as the lower bound model. A summary of the BE and LB modulus models used for the settlement calculations are shown on Figure 23.

7.1.4 Depth of Influence

In general, the stresses induced within the subsurface rock materials by foundation load decrease with depth. For settlement estimates, the depth of influence, or critical depth, is defined as follows:

- The minimum depth below the foundation at which the imposed vertical component of the stress diminishes to about 20 percent of the maximum stress applied by the foundation (Ref. 3.2.12).

- The minimum depth below the foundation where the applied stress due to foundation load decreases to 10 percent of the effective overburden pressure for fine-grained compressible materials or 20 percent for coarse-grained materials (Ref. 3.2.8).

7.2 Rebound Deformation

Rebound deformation due to general site elevation cuts or foundation excavations (i.e. foundation unloading) will be predominantly elastic in nature because of the relatively low imposed stress levels and nature of the subsurface rock materials. Rebound is based on the same methodology for settlement computation, with the exception that a negative load or stress release is applied instead of a positive load. The amount of the stress release is estimated based on the total weight of the soils or rocks planned to be excavated.

7.3 Liquefaction and Seismic Settlement

Soil liquefaction results from the earthquake-induced temporary buildup of excess pore water pressure in saturated granular materials, which can lead to a condition of near-zero effective stress and the temporary loss of strength. Ground shaking must be significant in intensity and of a long-enough duration to induce build-up of excess pore pressure. A reduction in soil strength due to liquefaction would lead to a reduction in resisting soil pressures, strain increase in buried structures, and potential loss of bearing capacity, settlement, and lateral spreading.

Soil materials considered to be susceptible to liquefaction include loose, saturated sands and non-plastic silts. Liquefaction commonly occurs in Holocene and late-Pleistocene age underconsolidated to consolidated saturated soils. The susceptibility of soils to liquefaction is a function of the distribution of grain sizes (gradation), soil density, cementation, total fines content, and plasticity characteristics of the fines. The resistance to liquefaction increases with increasing (a) grain size distribution, (b) soil density, (c) cementation, (d) fines content, and (e) plasticity characteristics of the fines.

The foundation basemats of all seismic category I and II structures are founded on engineering Layer C limestone, with the exception of seismic category I duct banks that are embedded in compacted fill adjacent to the nuclear island.

Permanent groundwater is generally below the residual soil and existing non-structural fill within the power block area. Any residual soils and nonstructural fill beneath or adjacent to structures will be removed and replaced with compacted fill. The compacted fill materials placed within the excavated areas around Units 3 and 4 and in the north-facing fill slopes are not considered prone to liquefaction for the following reasons:

- All fill material consists of engineered compacted fill with a minimum relative compaction of 95 percent (ASTM D1557). The corrected/normalized standard penetration test N-Values are expected to be higher than 30 blows per foot, which is outside the range considered susceptible to soil liquefaction.

- The engineered compacted fill materials are not in a saturated state. The permanent groundwater table is well below the engineered compacted fill materials.

- The site is in an area of very low seismicity. The results of the ground motion and site response analyses indicate that the peak ground acceleration (PGA) ranges between 0.046g and 0.077g (Ref. 3.1.24).

Even in the unlikely event that the engineered compacted fill surrounding the main plant area becomes completely saturated due to potential development of perched groundwater level, the soil density is too high and the site strong ground motions are too low to suggest any potential for liquefaction. Liquefaction analyses were also performed for compacted fill under the assumption of saturated conditions and a lower standard penetration test N-Value of 25 to demonstrate that, in the unlikely event that the groundwater table is risen to the proposed site yard grade (elevation 822 feet), the compacted fill will not be subject to liquefaction. Details of the calculations and results are presented in Appendix D. These analyses indicate that the potential for liquefaction for compacted fill in a saturated condition at this site is very low.

7.4 Bearing Capacity

Major structures for Units 3 and 4 will be founded on mat foundations bearing on fairly intact Glen Rose Formation bedrock, or on concrete fill placed after shale materials are removed. Ultimate bearing capacity of the Glen Rose rock mass was estimated for three potential failure mechanisms of general shear failure, local shear failure, and compressive failure as presented in the Rock Foundations Manual by the U.S. Army Corps of Engineers (EM 1110-1-2908, Ref. 3.2.12).

7.4.1 General Shear Failure

The U.S. Army Corps of Engineers EM 110-1-2908 (Ref. 3.2.12) recommends the traditional Buisman-Terzaghi (Terzaghi, 1943) bearing capacity expression to calculate ultimate bearing capacity for general shear failure mode as shown below.

$$q_{ult} = cC_c N_c + 0.5\gamma B C_\gamma N_\gamma + \gamma D N_q$$

$$N_c = 2N_\phi^{1/2}\left(N_\phi + 1\right)$$

$$N_\gamma = N_\phi^{1/2}\left(N_\phi^2 - 1\right)$$

$$N_q = N_\phi^2$$

$$N_\phi = \tan^2\left(45 + \frac{\phi}{2}\right)$$

Where:

q_{ult}	=	Ultimate bearing capacity
γ	=	Effective unit weight (i.e. submerged unit weight if below groundwater table) of rock mass
B	=	Width of foundation
D	=	*D*epth of foundation embedment

c = The cohesion intercept for rock mass

ϕ = Angle of internal friction angle for rock mass

C_c = Foundation shape correction factor for N_c (see Table 7.4.1-1 below)

C_γ = Foundation shape correction factor for N_γ (see Table 7.4.1-1 below)

N_c, N_γ, N_q = Bearing capacity factors

Table 7.4.1-1 Foundation Shape Correction Factors

Foundation Shape	C_c (N_c Correction)	C_γ (N_γ Correction)
Circular	1.2	0.70
Square	1.25	0.85
Rectangular		
L/B = 2	1.12	0.90
L/B = 5	1.05	0.95
L/B = 10	1.00	1.00

7.4.2 Local Shear Failure

Local shear failure represents a special case where a failure surface starts to develop but does not propagate to the surface. For this mode of failure, depth of embedment contributes little to the total bearing capacity. The expression for the ultimate bearing capacity applicable to localized shear failure is as follows:

$$q_{ult} = cC_cN_c + 0.5\gamma BC_\gamma N_\gamma$$

The parameters are the same as those defined in Section 7.4.1.

7.4.3 Compressive Failure

Compressive failure is a case characterized by a foundation that is supported on poorly constrained columns of rock, and the failure mode will be similar to unconfined compression failure. The ultimate bearing capacity may be estimated as shown below:

$$q_{ult} = 2c\tan(45 + \frac{\phi}{2})$$

The parameters are the same as those defined in Section 7.4.1. Using unconfined compression strength parameters (q_{ult}=2c) by assuming ϕ=0, the ultimate bearing capacity is approximated by the unconfined compressive strength of rock mass.

7.4.4 Bearing Capacity Parameter Selection

For selecting the design parameters, the U.S. Army Corps of Engineers (Ref. 3.2.12) recommends that because rock masses generally provide generous margins of safety against bearing capacity failure, the initial strength parameter values selected for assessing bearing capacity should be based on lower bound estimates. In general, as a conservative estimation of the bearing capacity using the above procedures, the angle of internal friction (ϕ) is assumed to be zero, and the cohesion is taken as one-half of the lower bound of the unconfined compression strength value.

8.0 CALCULATIONS

8.1 Settlement

Settlement and deformation analyses were conducted using both the non-layered and layered methods described above for the two best estimate and lower bound deformation modulus models that were described in Sections 6.1.1 and 6.1.2. As discussed in Section 5.4.3, it is assumed that the groundwater level at the site may rise to elevation 804 ft. However, for conservatism and in order to estimate the maximum potential settlement, the groundwater level in the analysis was set at a level below the foundations to disregard the buoyancy effect of the foundation loads. Information on the T/B loads are not yet available. However, a conservative estimate of 10 ksf was considered to incorporate the impact of the T/B on the settlements in the other buildings. The T/B had minimal impact on the settlements of adjacent buildings with settlements increasing within the R/B complex by up to 10%. A summary of the settlement results for the center points of the main buildings is shown in Tables 8.1-1 and 8.1-2:

Table 8.1-1: Settlement Estimates Based on Best Estimate Modulus Model

Structure	Foundation Static Load (ksf)	Settlement Estimate for Center, inches	
		Non-Layered Method	Layered Method
R/B Complex	13.1	0.17	0.29
PSFSV	4.0	0.10-0.12	0.13-0.17
UHSRS	4.9	0.08	0.10

Table 8.1-2: Settlement Estimates Based on Lower Bound Modulus Model

Structure	Foundation Static Load (ksf)	Settlement Estimate for Center, inches	
		Non-Layered Method	Layered Method
R/B Complex	13.1	0.45	0.52
PSFSV	4.0	0.26-0.30	0.22-0.28
UHSRS	4.9	0.22	0.18

Settlement calculations and results for additional corner points of the structures are provided in Appendix A. The differential settlement is anticipated to be about ½ the total settlement values. Due to lack of available loading or dimensions, no settlement calculations were performed for the ESWPT. However, the loads for these structures are expected to be very minimal and, consequently, the resulting settlements likely are insignificant.

Additional settlement analyses were also performed using non-uniform load distributions for the reactor building complex. The foundation area for the reactor building complex was divided into nine zones based on estimates of the project-specific distribution of structural loads generated from Ref. 3.1.12, 3.1.21, and 3.1.22. Figure 24 shows an idealized approximation of the bearing pressures for each zone of the R/B complex. Foundation settlements were calculated along seven east-west and seven north-south lines (also shown on Figure 24) for both the lower bound and best estimate/upper bound rock profiles. Settlement profiles along these lines are presented on Figures 25 and 26 for lower bound and best estimate modulus values for profiles along the R/B complex east-west axis and Figures 27 and 28 for profiles along the R/B complex north-south axis, respectively. Details of the calculations are presented in Appendix E. For the lower bound properties, a maximum settlement of 0.41 inch was estimated, with the largest differential settlement within or between any of the seven lines in either direction estimated at 0.30 inch. For the best estimate rock properties, maximum, minimum, and largest differential settlements of 0.22, 0.07, and 0.15 inch, respectively, were estimated. Assuming that the R/B complex is partially supported on rock with the lower bound properties and partially on rock with the best estimate properties, the maximum differential settlement across the foundation along the profiles shown on Figure 24 would be less than 0.34 inch (0.41 inch - 0.07 inch = 0.34 inch).

Considering the settlement patterns shown on Figures 25 through 28 and with a conservative assumption that the R/B complex is partially supported on rock with the lower-bound properties and partially on rock with the best-estimate properties, the maximum potential angular distortion of the reactor building complex foundation (near the extreme location of foundation edges) is not likely to exceed approximately 1/3000. The potential tilt of the reactor complex across the foundation along the width or the length would be much less. Furthermore, those estimates are conservative because the rigidity of the foundation mat was ignored in the settlement calculations. The mat foundation will reduce differential settlements from those estimated herein.

Based on the results of the settlement estimates, the proposed structures are not anticipated to experience any settlements in excess of 0.52 inches, which is well within the acceptable settlement criteria of a mean of 8.4 inches total and 5.4 inches differential settlement, as defined in Ref. 3.1.23. Maximum differential settlements between buildings would be less than the acceptable target of 0.4 inch and the maximum tilt of the R/B complex foundation will not exceed the acceptable target of 1/3000 (Ref. 3.1.23).

8.2 Depth of Influence or Critical Depth

For the settlement calculations using the layered system, a depth of about 1000 feet below the elevation 822 feet was used in the settlement model. The depths of influence, or critical depths as defined by the criteria of 10-20 percent of the effective overburden pressure (Section 7.1.4) for the structures, are shown on the stress distribution plots in Appendix A. The minimum

depths of influence for all structures are generally less than the actual depth used in the settlement calculations.

8.3 Rebound Deformation

Rebound deformation estimates were carried out by both the non-layered and layered methods described above for the best estimate deformation modulus model described in Section 6.1.1. A summary of the rebound estimates for the center points of the main buildings are shown in Table 8.3-1:

Table 8.3-1: Rebound Estimates Based on Best Estimate Modulus Model

Structure	Excavation Depth, ft	Rebound Estimate for Center, inches	
		Non-Layered Method	Layered Method
R/B Complex	40-50	0.09	0.14
PSFSV	40-50	0.06-0.07	0.08-0.10
UHSRS	40-50	0.06	0.09

Rebound calculations and results for additional corner points of the structure areas are provided in Appendix B. The rebound values were estimated based on the removal of about 40 feet of soil and rock material to the top of Layer C limestone rock. Based on the results of the rebound estimates, the potential for any significant heave or rebound of the foundation rock due to foundation excavation during the construction is very low.

8.4 Bearing Capacity

Bearing capacity estimates for the three failure modes and the minimum factors of safety are summarized in Table 8.4-1. The lowest estimated bearing capacity of about 146 ksf for all seismic category I and II foundations is for the compressive failure mode. The calculations are presented in Appendix C.

Table 8.4-1: Summary of Ultimate Bearing Capacities

Structure	Foundation Load (ksf)		Ultimate Bearing Capacity (ksf)			Available FOS	
	Static Load	Seismic Load	General Shear	Local Shear	Compression	Static	Seismic
R/B Complex	13.1	20.9	367	364	146	11.1	7.0
T/B	--	--	356	354	146	--	--
T/G	--	--	318	315	146	--	--
PSFSV	4.0	7.6	367	364	146	36.5	19.2
UHSRS	4.9	14.9	343	340	146	29.8	9.8
ESWPT	4.6	8.5			146	31.7	17.2

Based on the above results, the compression failure mode governs and results in an ultimate bearing capacity of about 146 ksf. From the available factors of safety shown above, the Glen Rose Limestone of Layer C appears to provide adequate bearing capacity for support of the proposed structures.

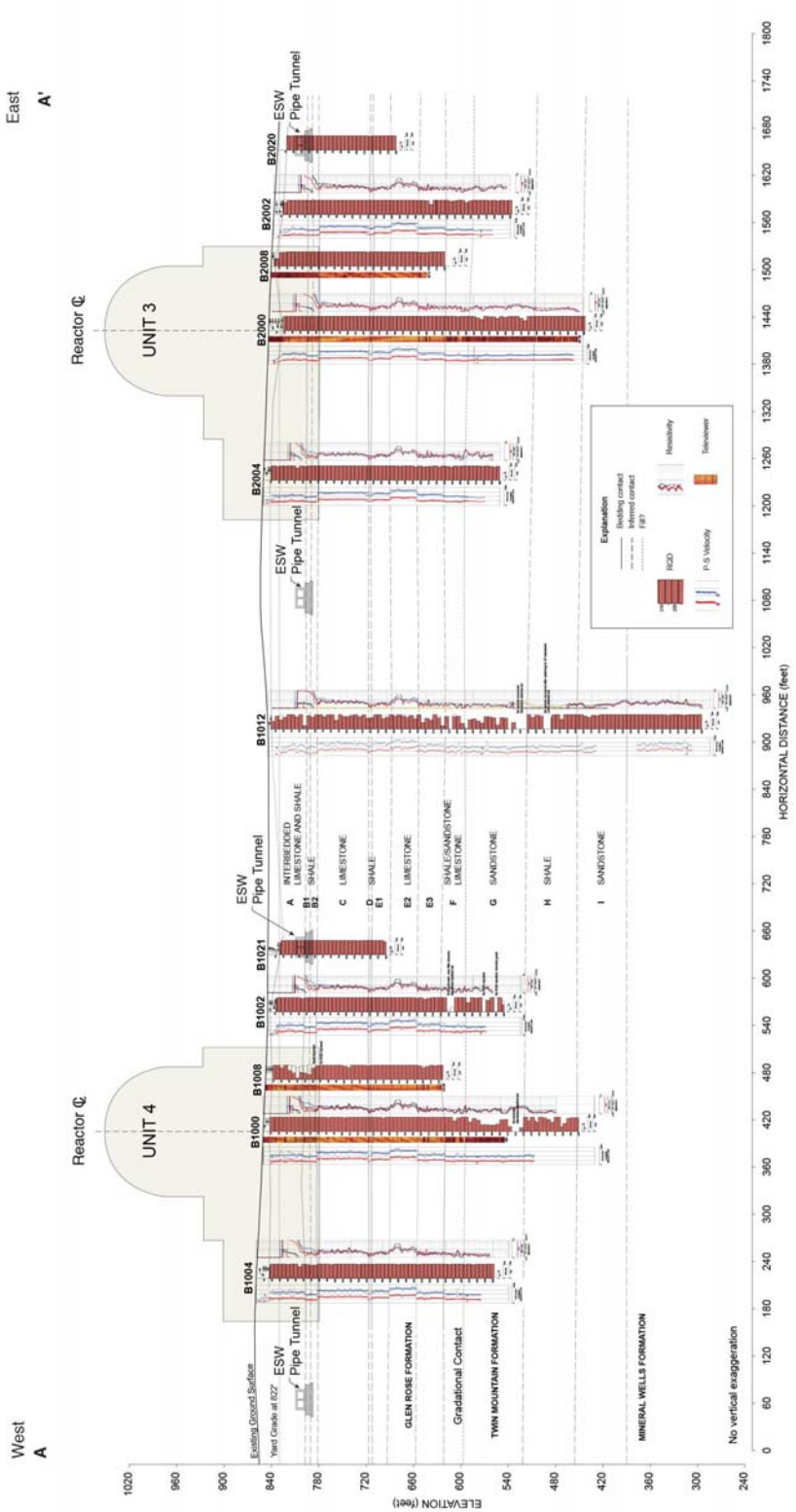
9.0 SOFTWARE

Microsoft Excel and Mathcad are the only sofware programs used for all calculations provided in this report. In general, all calculations were performed with Microsoft Excel, and the same calculations were repeated using the Mathcad program. The duplicate calculation results obtained through using the Mathcad were used to serve as a hand-check for the results obtained by the Excel for the same problem and the input data. The software versions utilized for this calculation package are as follows:

- Microsoft Office Excel 2010
- Mathcad – 2007 Version 14.0

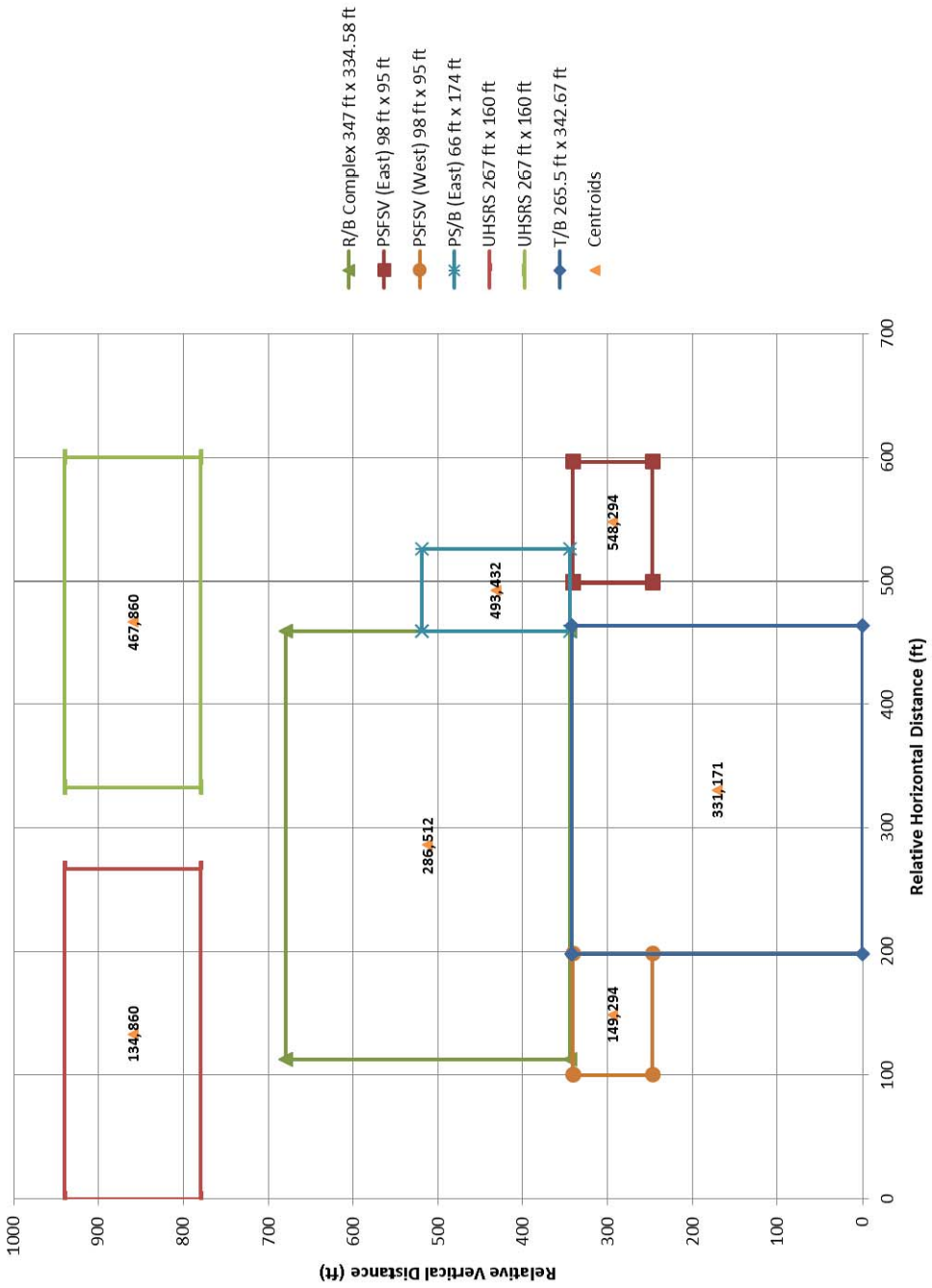
As-Built Exploration Locations

FIGURE 1



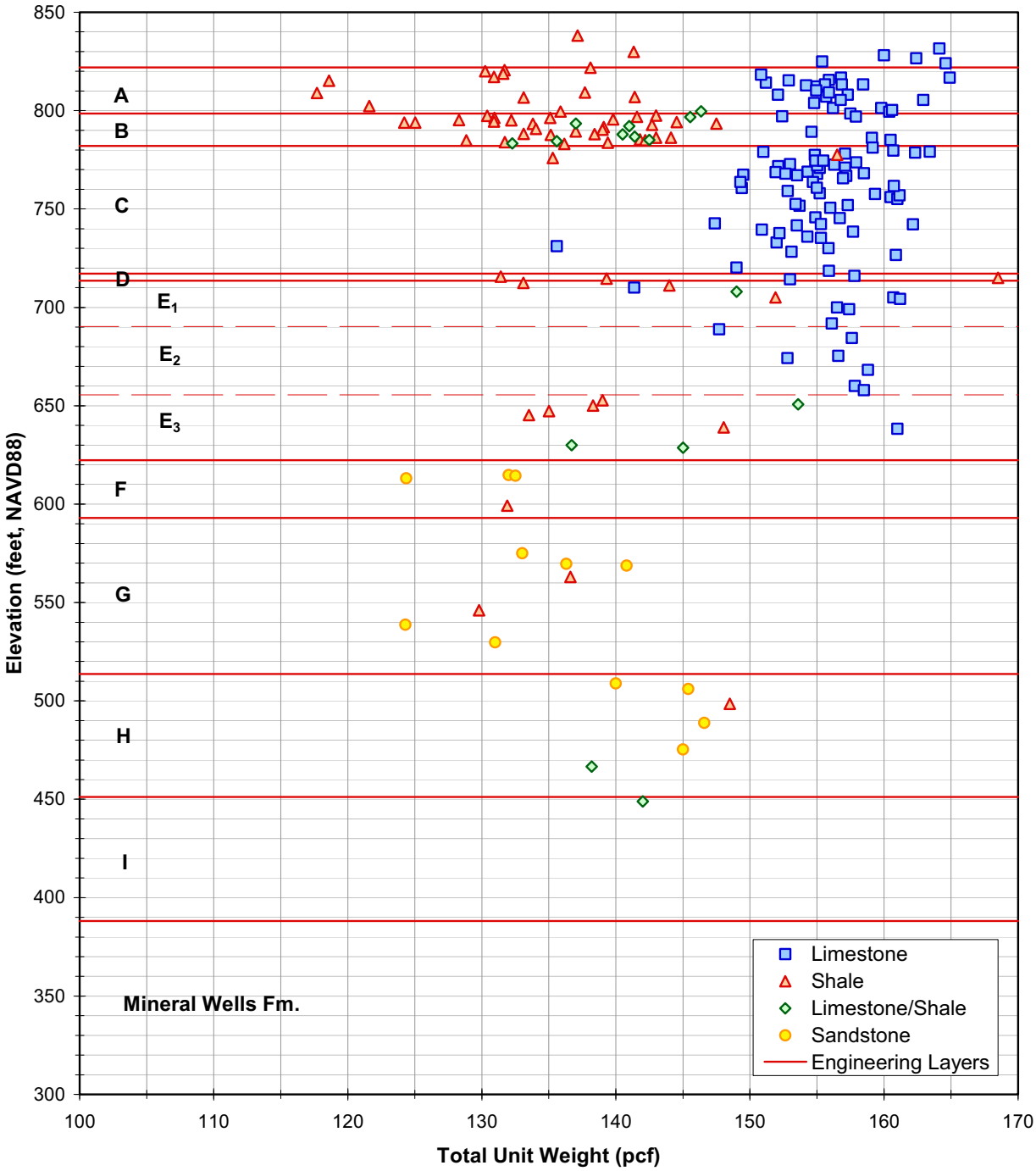
Engineering Cross Section

FIGURE 2



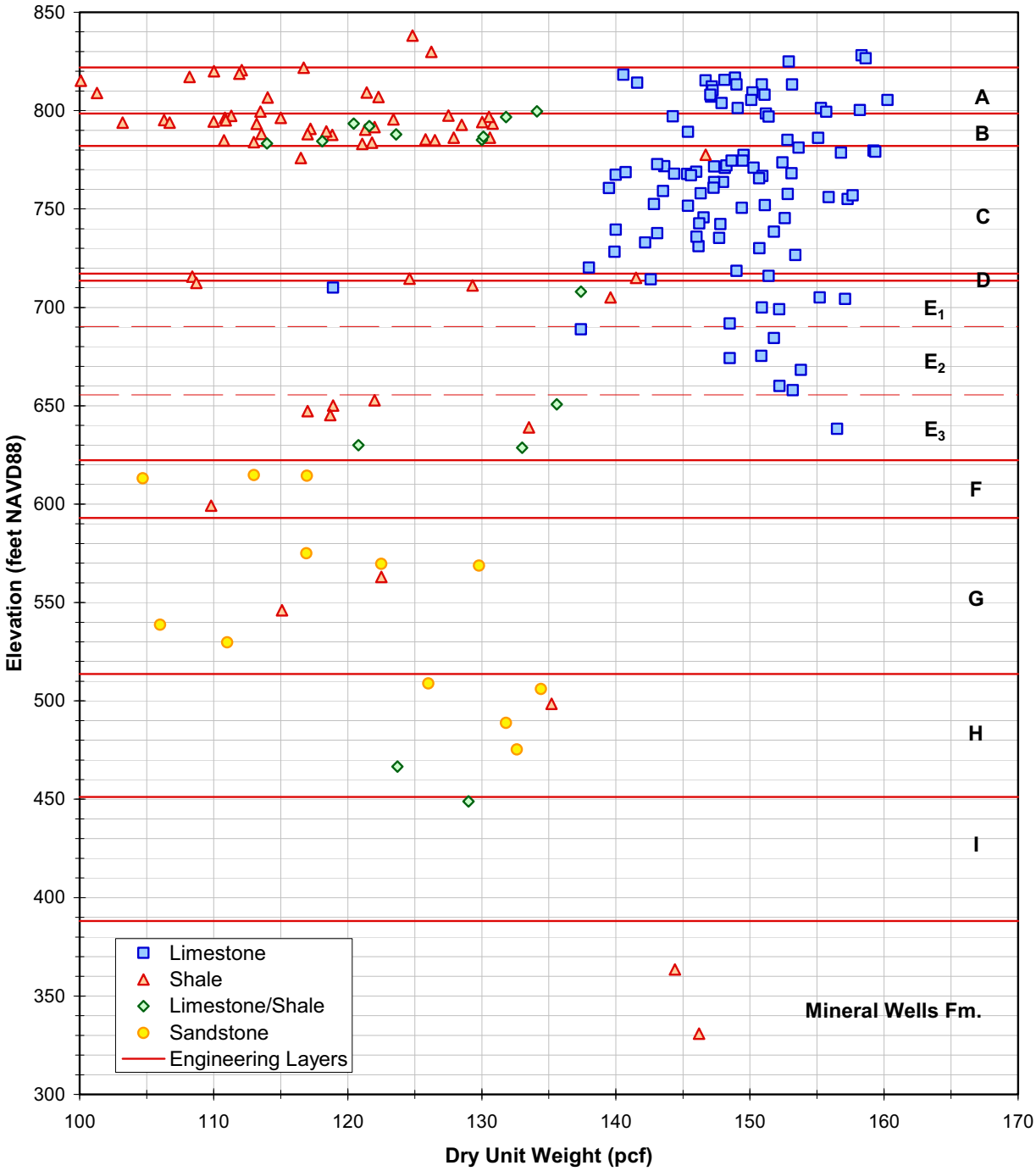
Unit Area Structure Layout

FIGURE 3



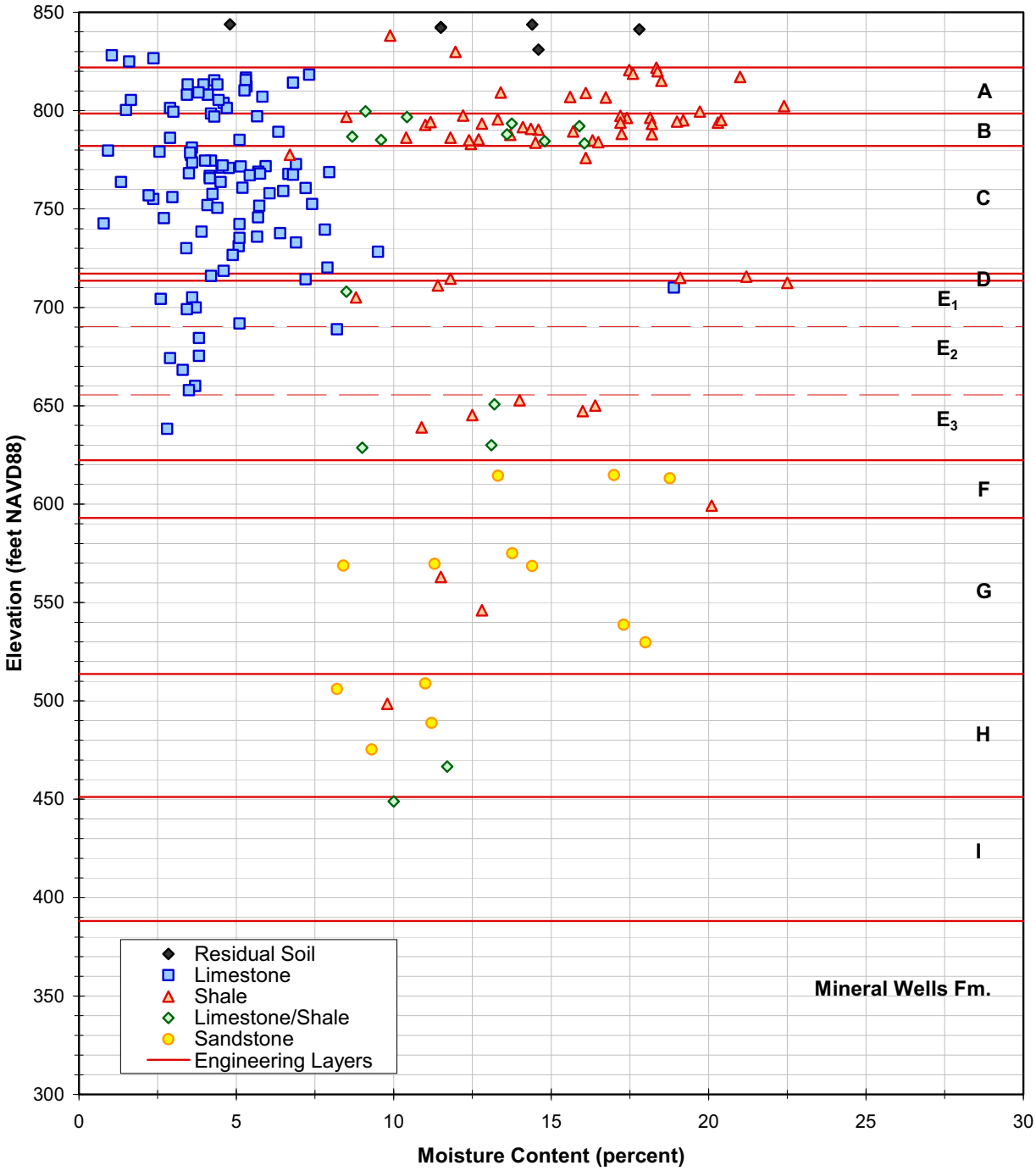
Total Unit Weight vs. Elevation

FIGURE 4



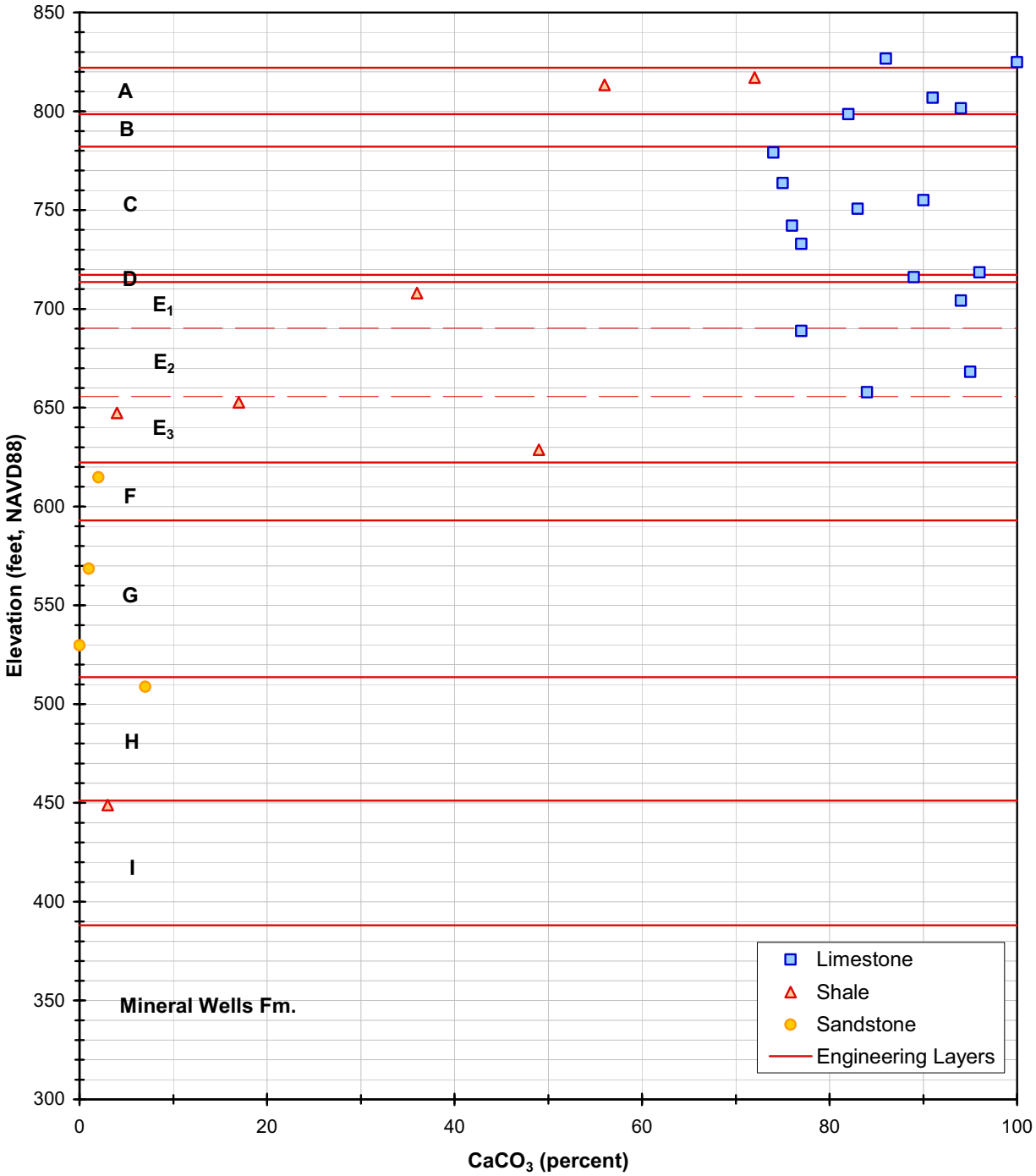
Dry Unit Weight vs. Elevation

FIGURE 5



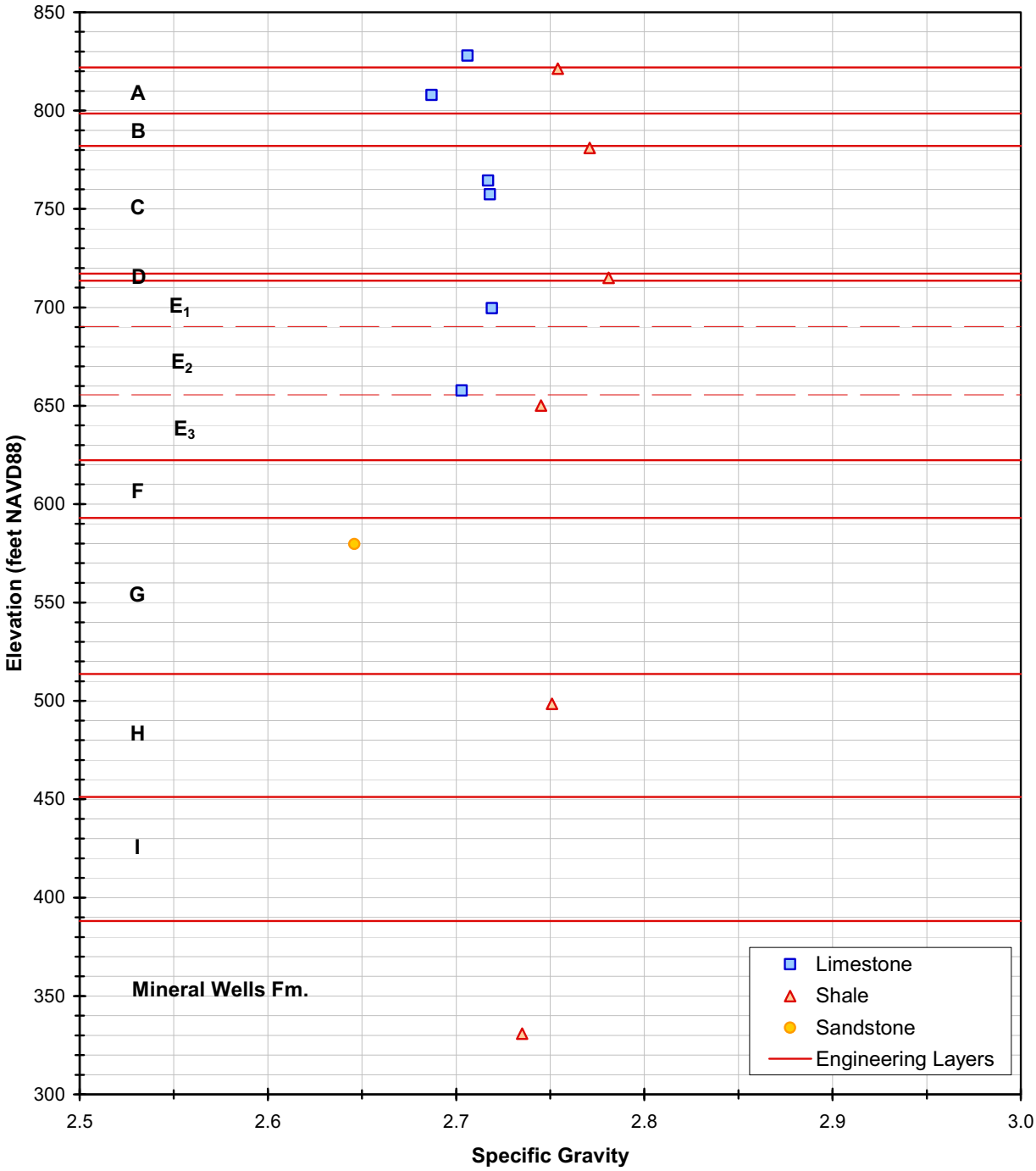
Moisture Content vs. Elevation

FIGURE 6



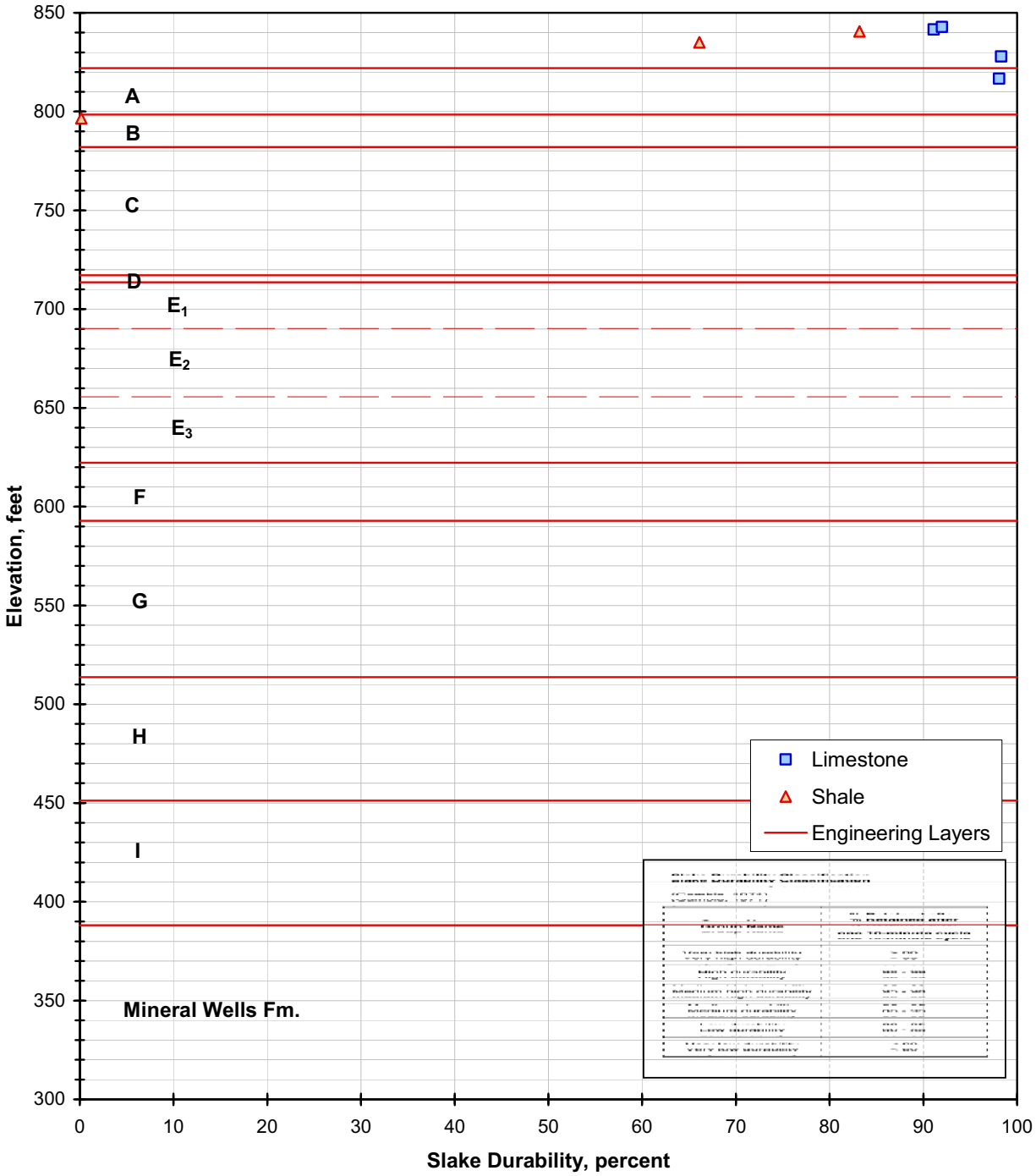
Calcium Carbonate vs. Elevation

FIGURE 7



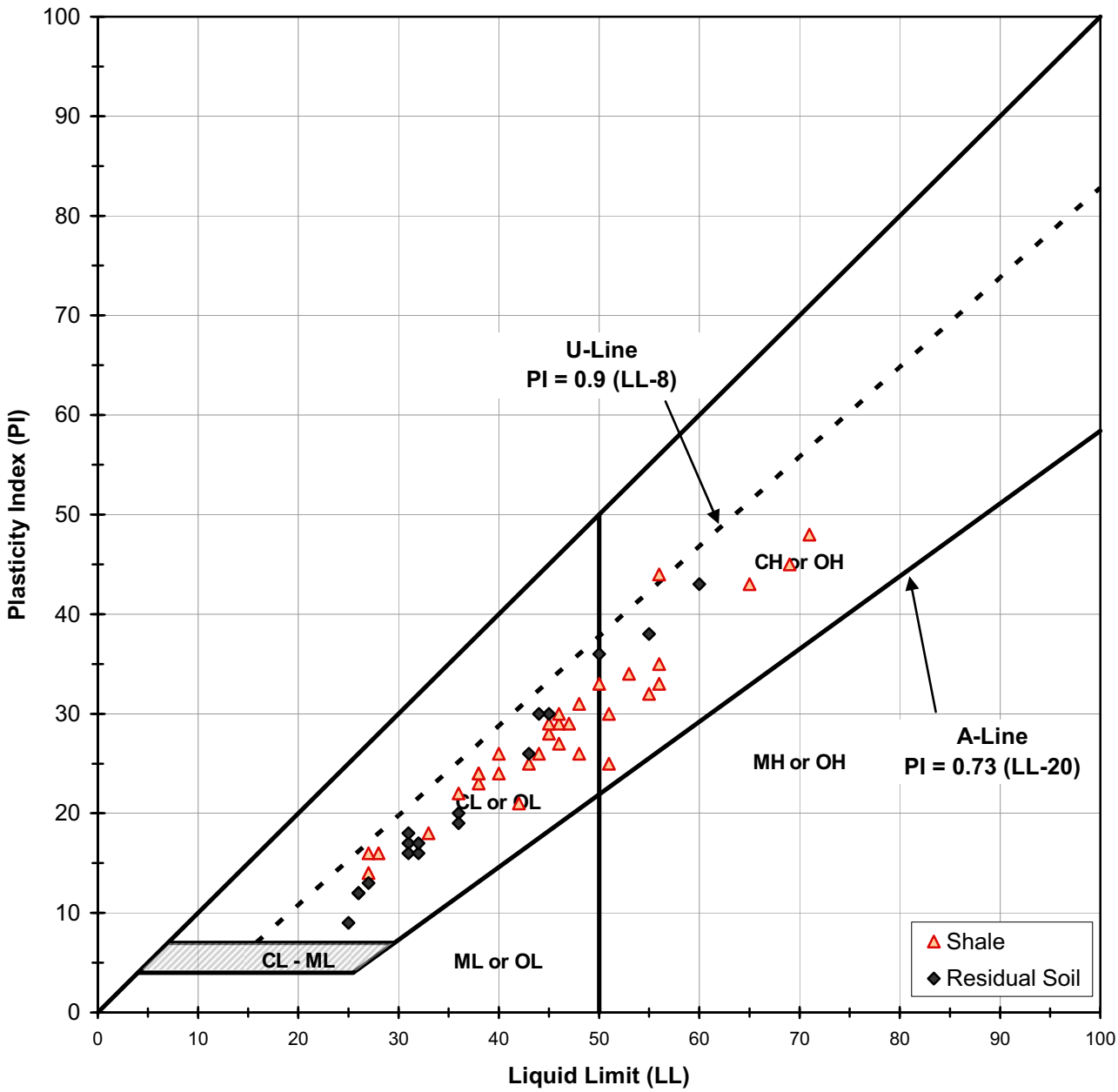
Specific Gravity vs. Elevation

FIGURE 8



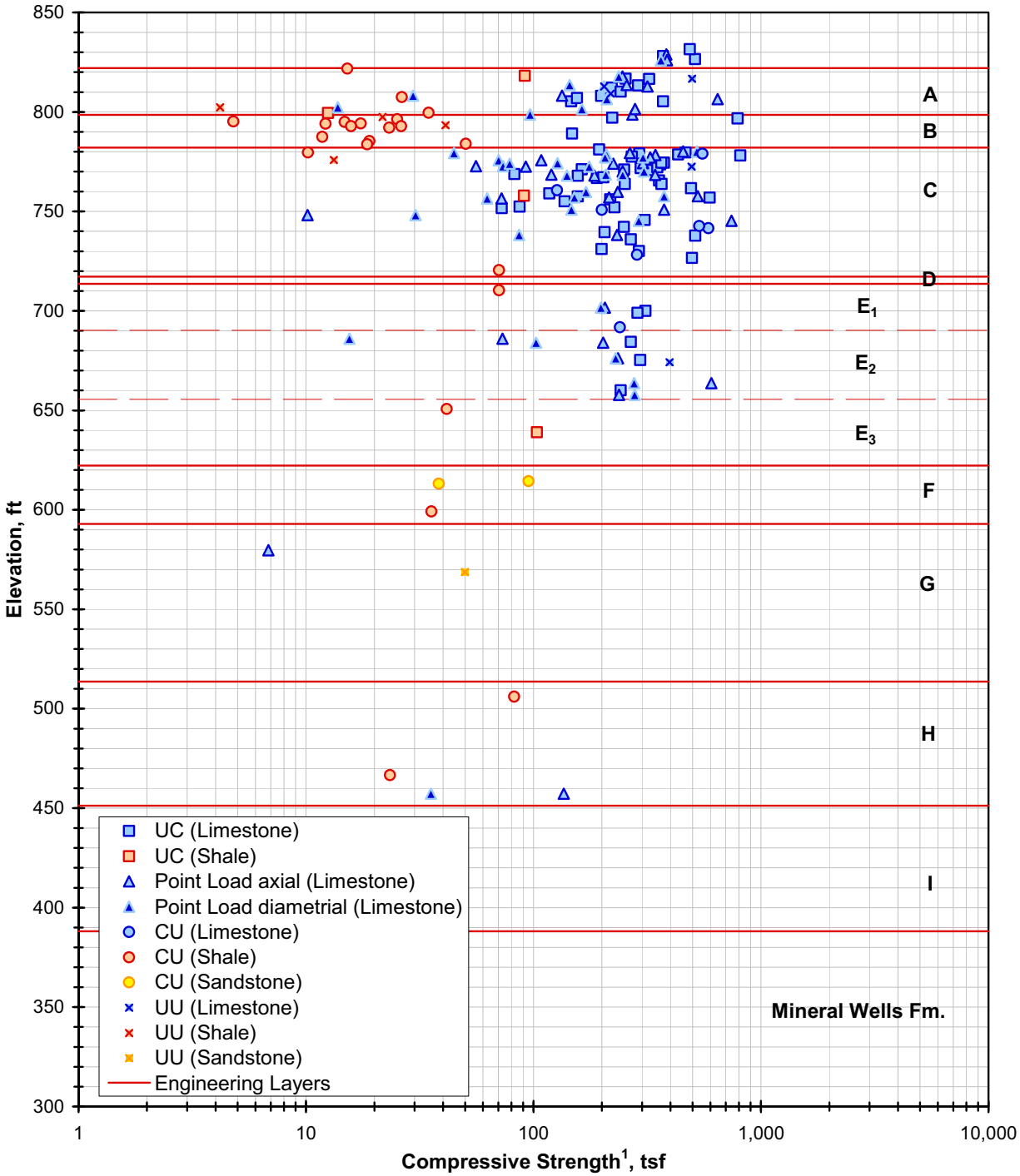
Slake Durability vs. Elevation

FIGURE 9



Plasticity Data

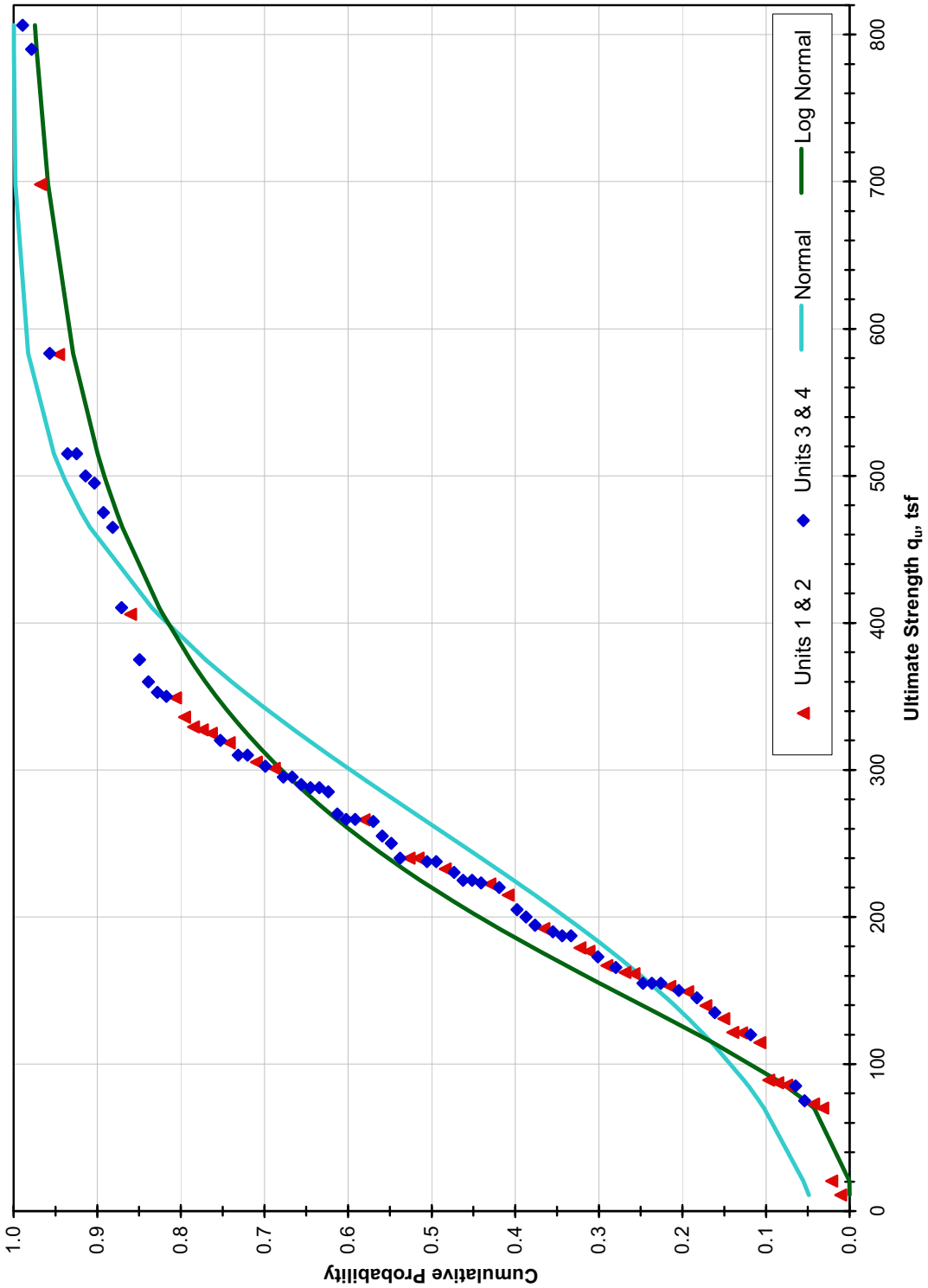
FIGURE 10



Notes:
1- Uniaxial stress for UC and PLI tests and deviator stress for CU and UU tests

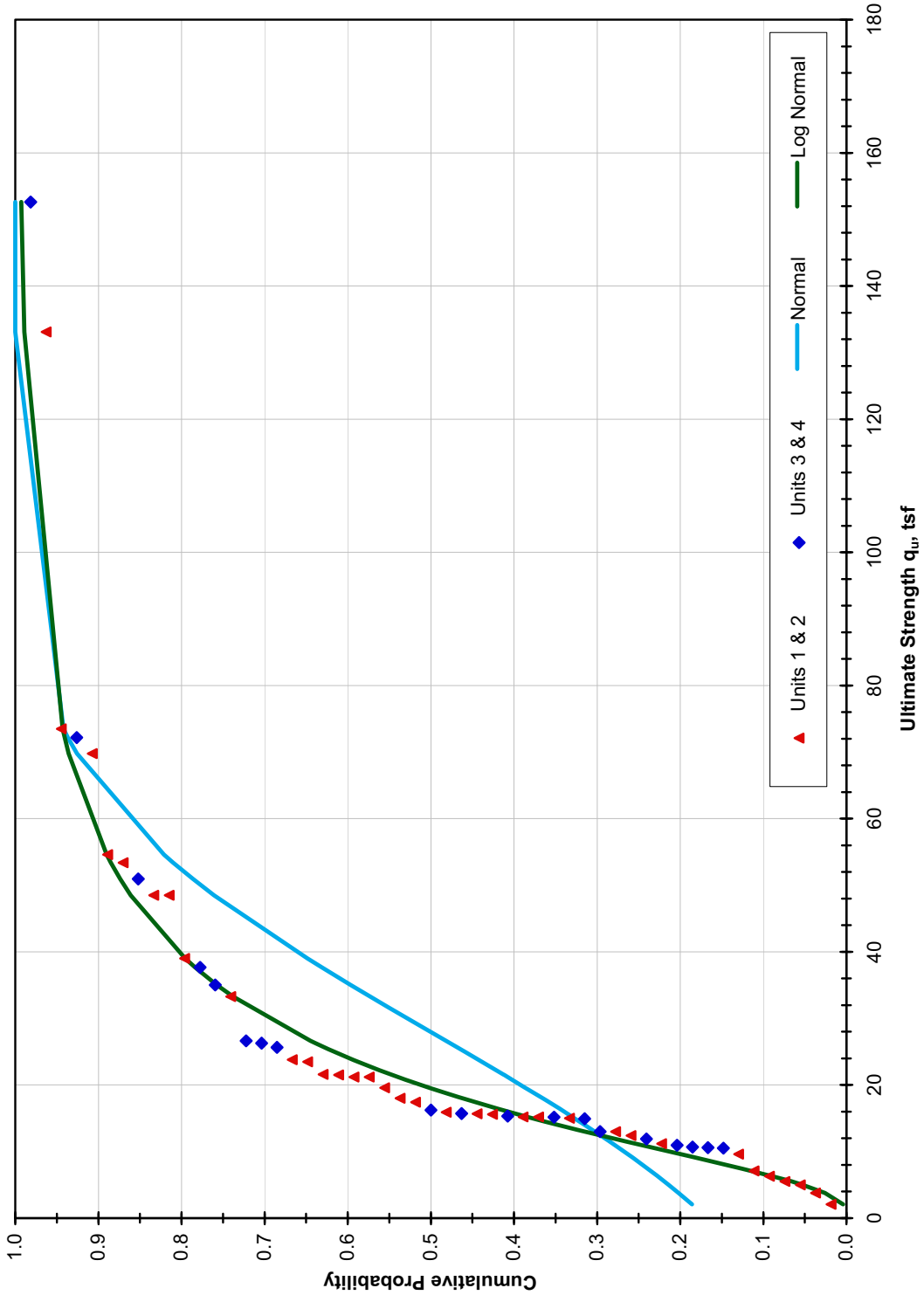
Compressive Strength vs. Elevation

FIGURE 11



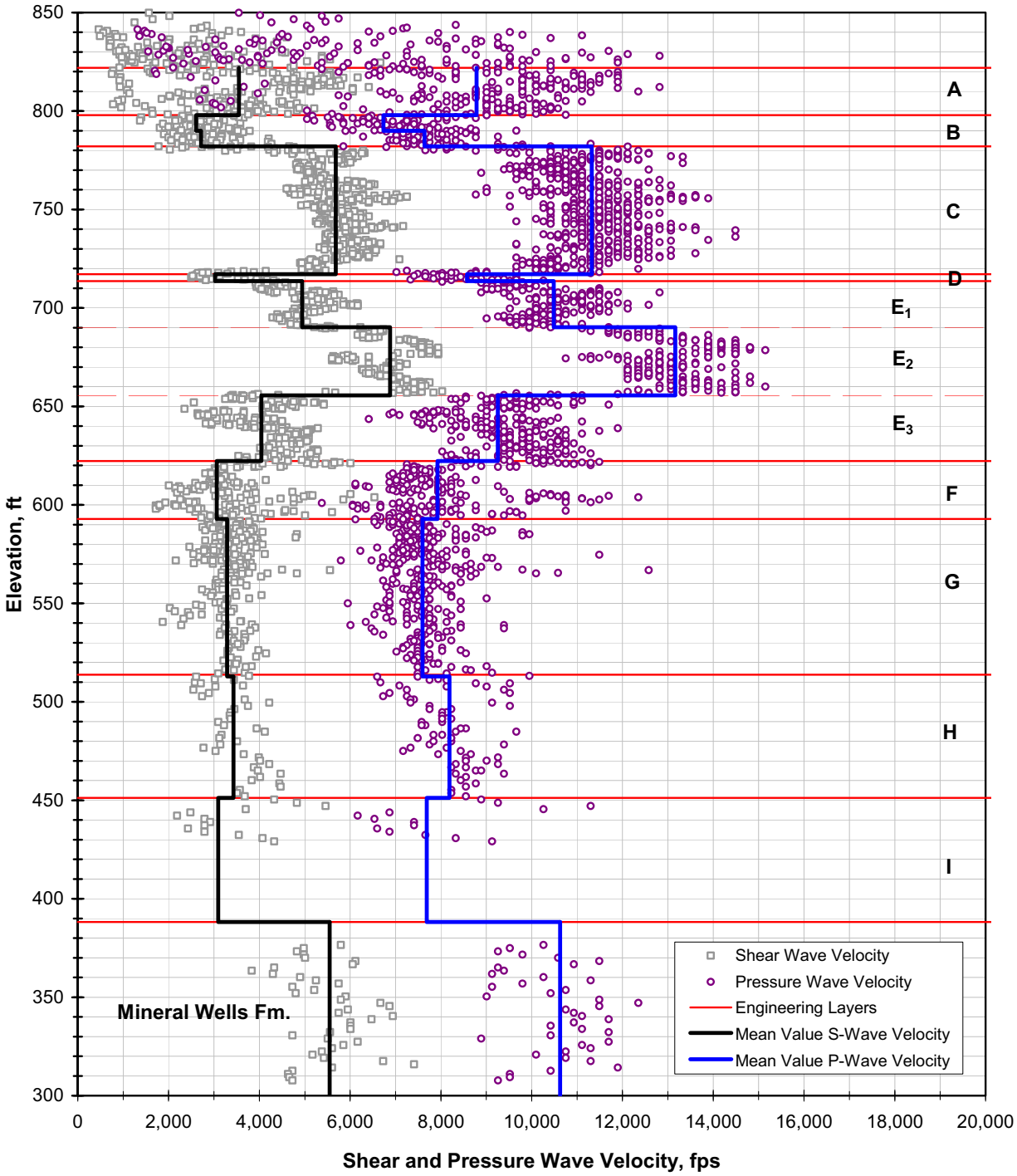
Cumulative Probability of Unconfined Compressive Strength Data
Limestone Samples

FIGURE 12



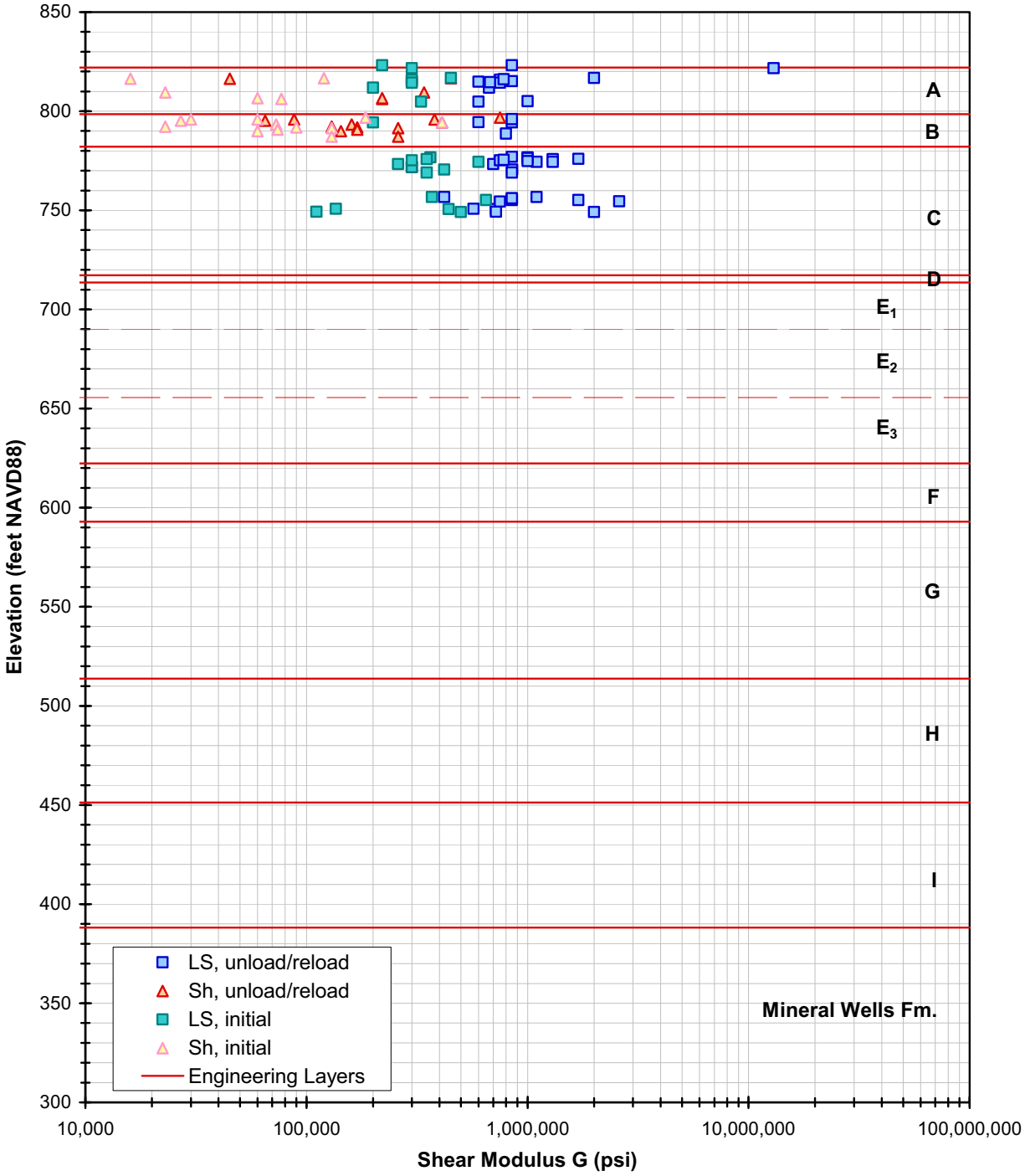
Cumulative Probability of Unconfined Compressive Strength Data
Shale Samples

FIGURE 13



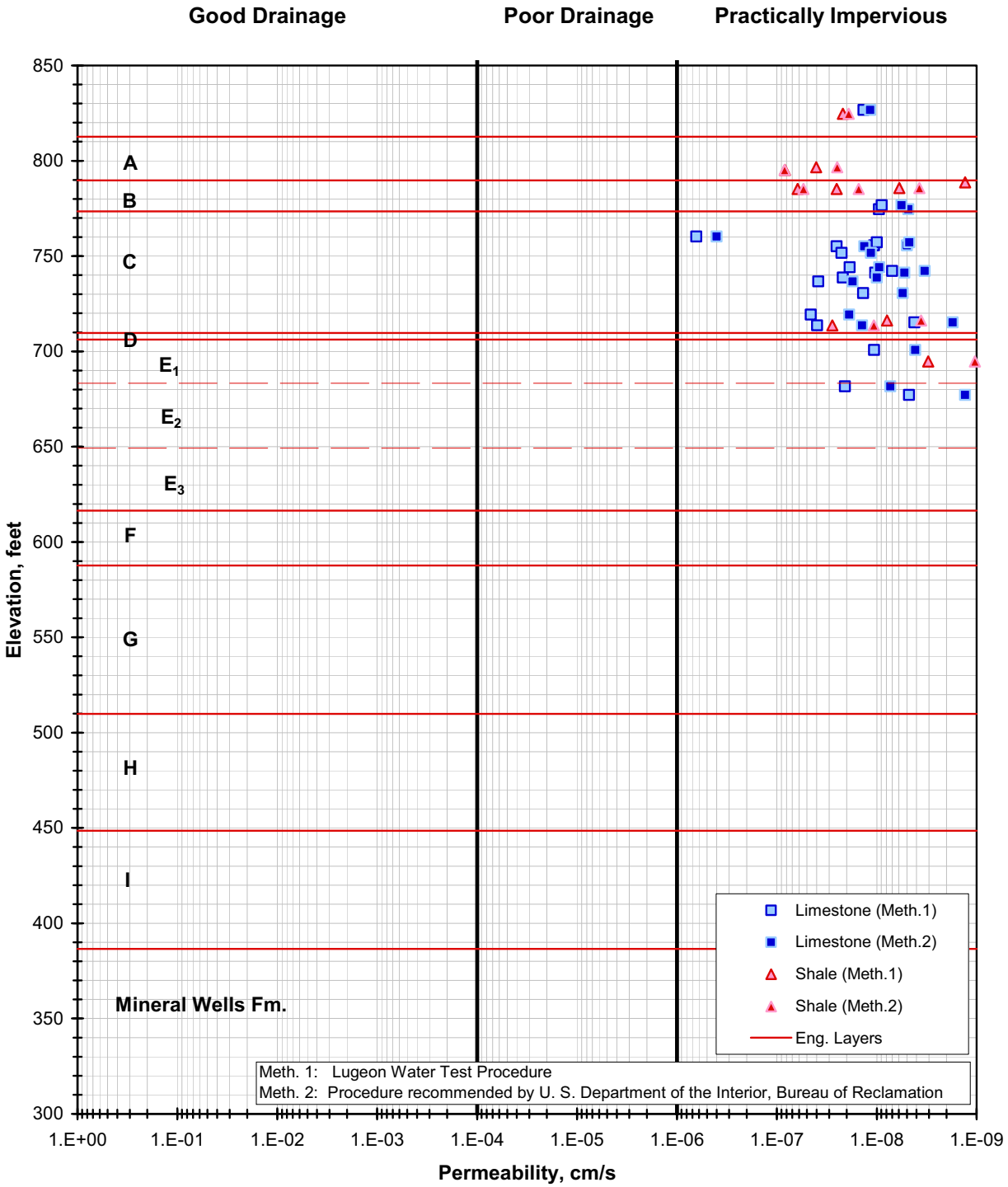
In Situ S- and P-Wave Velocity vs. Elevation

FIGURE 14



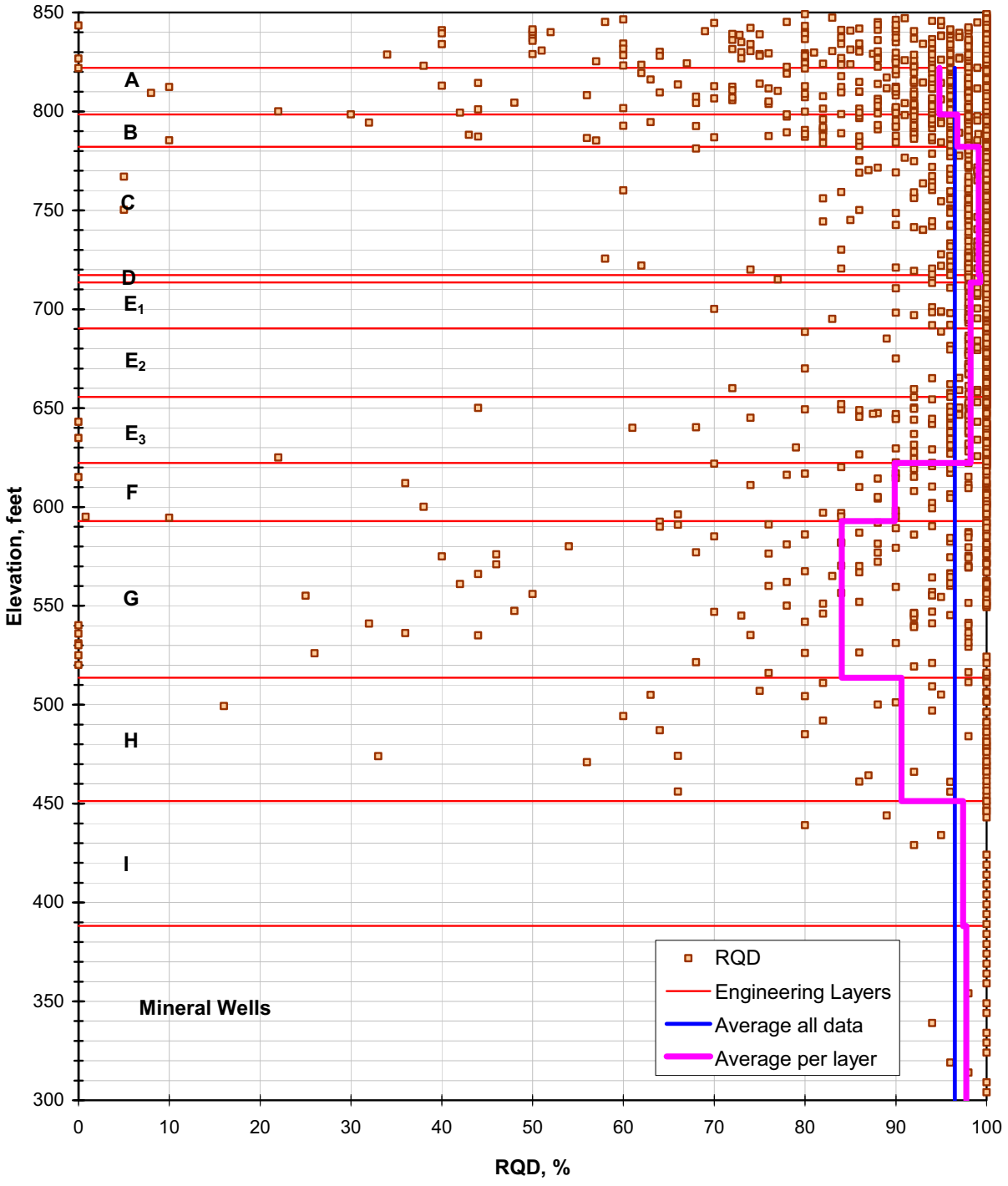
Shear Modulus vs. Elevation
Pressuremeter Tests

FIGURE 15



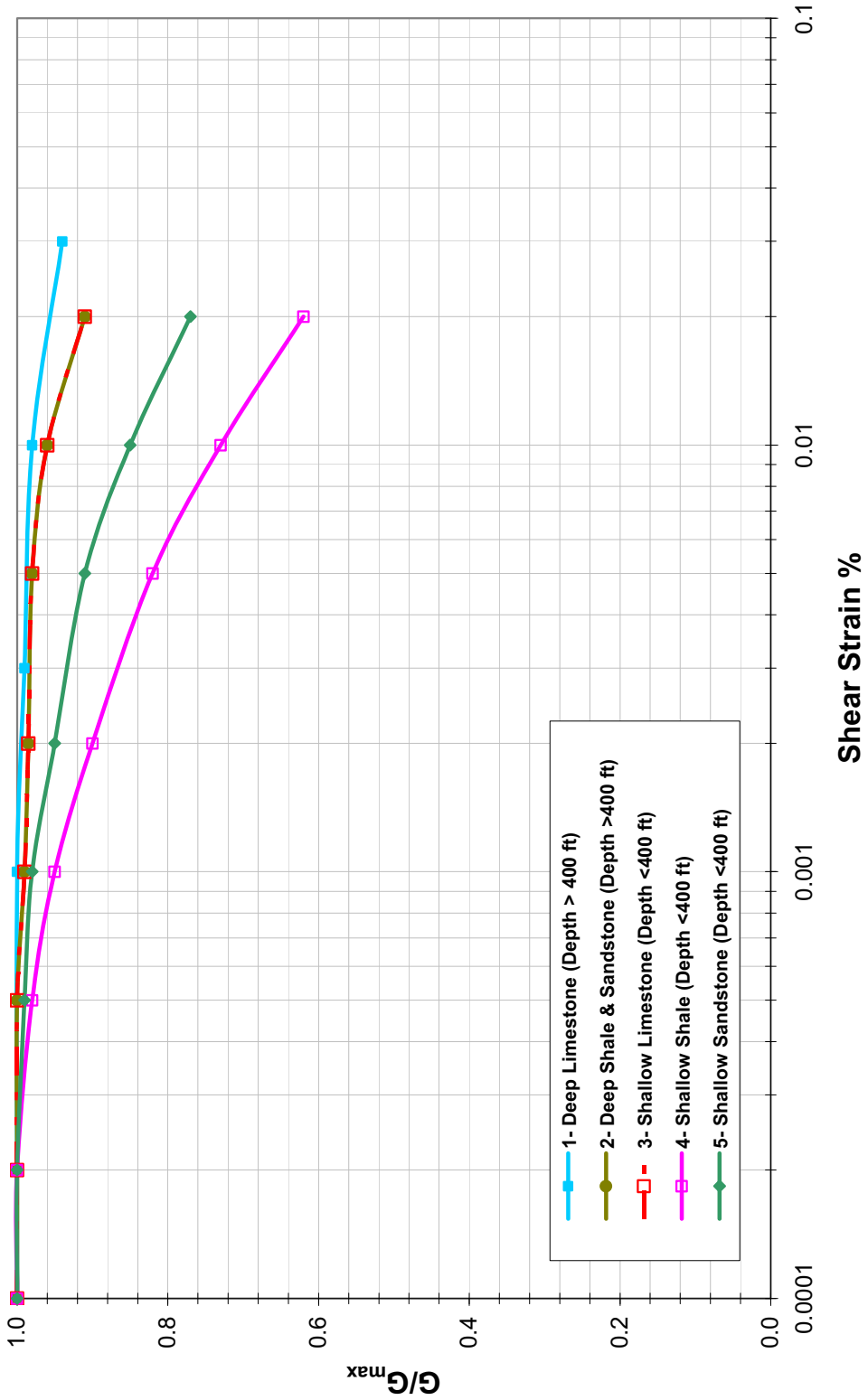
In Situ Packer Test Permeability vs. Elevation

FIGURE 16



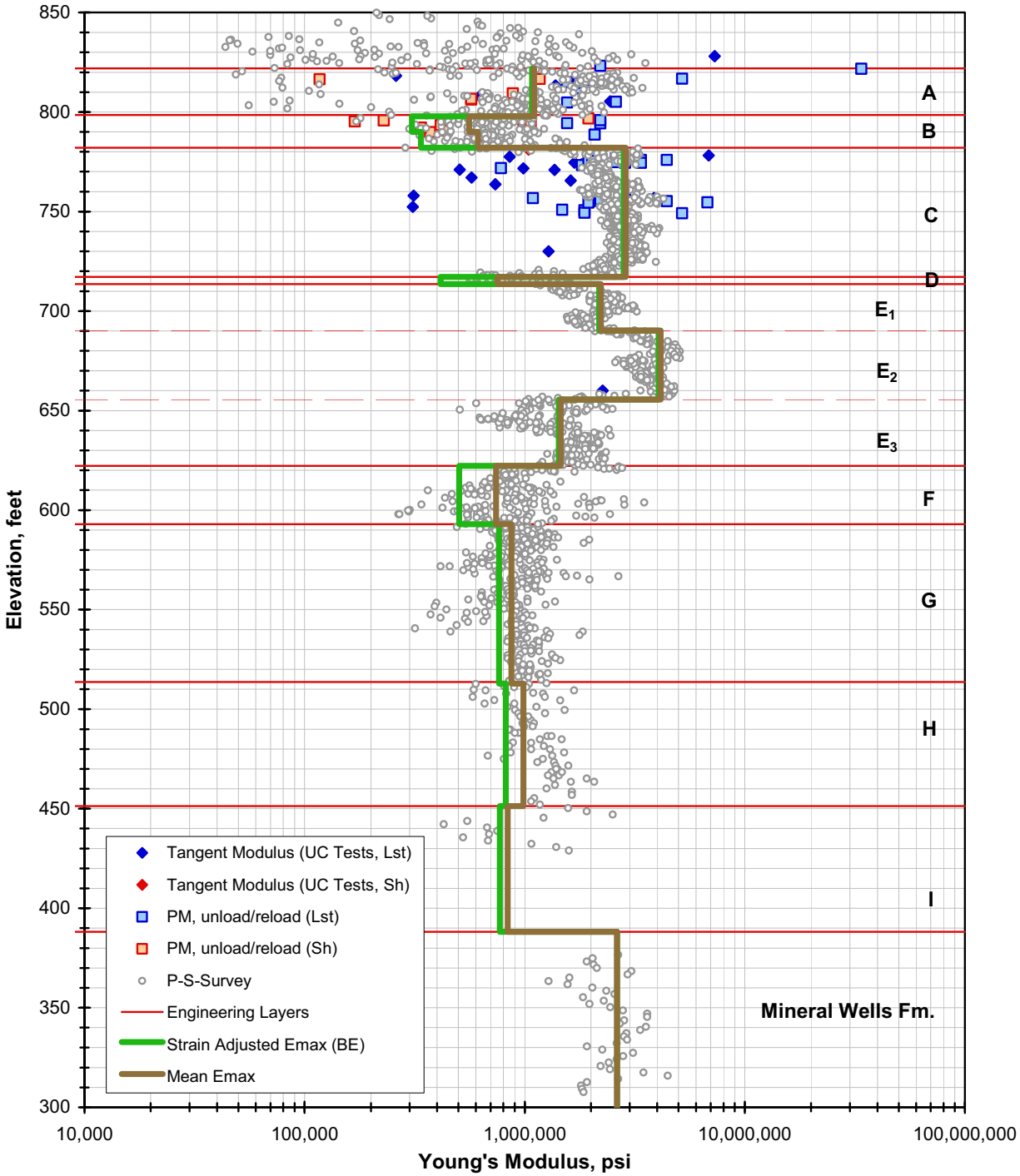
Rock Quality Designation vs. Elevation

FIGURE 17



G/G_{max} vs. Strain for Rock Materials

FIGURE 18



Young's Modulus vs. Elevation

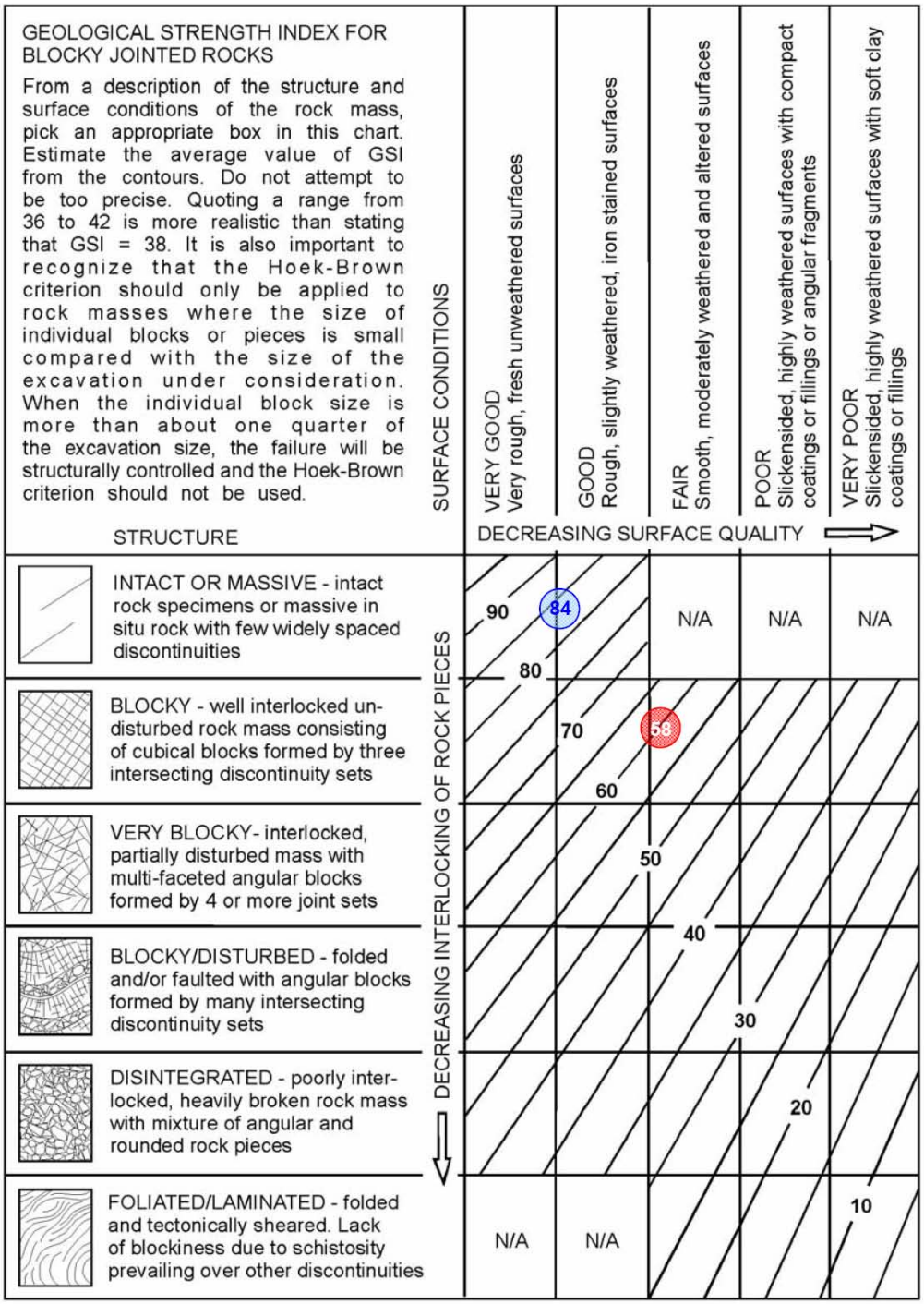
FIGURE 19

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS		ROCK MASS RATING SYSTEM (after Bieniawski 1989)							PROJECT PARAMETERS									
Parameter		Range of values							A	B	C	D	E	F	G	H	I	MW
1 Strength of intact rock material	Point-load strength index	>10 MPa	4 - 10 MPa	2 - 4 MPa	1 - 2 MPa	For this low range - uniaxial compressive test												
	Uniaxial comp. strength	>250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5 - 25 MPa	1 - 5 MPa	<1MPa	19	5	24	5	24	10	19	19	19	29
Rating		15	12	7	4	2	1	0	2	1	2	1	2	2	2	2	2	4
2 Drill core Quality RQD		90% - 100%	75% - 90%	50% - 75%	25% - 50%	< 25%			85	80	95	60	95	95	90	95	99	99
Rating		20	17	13	8	3			17	17	20	17	20	20	17	20	20	20
3 Spacing of discontinuities		> 2 m	0.6 - 2 m	200 - 600 mm	60 - 200 mm	< 60 mm			0.6 - 2 m	200 - 600 mm	0.6 - 2 m	200 - 600 mm	0.6 - 2 m	0.6 - 2 m	> 2 m	> 2 m	> 2 m	> 2 m
Rating		20	15	10	8	5			15	10	15	10	15	15	20	20	20	20
4 Discontinuity length (persistence)		< 1 m	1 - 3 m	3 - 10 m	10 - 20 m	> 20 m			< 1 m	1 - 3 m	< 1 m	1 - 3 m	< 1 m	1 - 3 m	< 1 m	< 1 m	< 1 m	< 1 m
Rating		6	4	2	1	0			6	4	6	4	6	4	6	6	6	6
Separation (aperture)		None	< 0.1 mm	0.1 - 1.0 mm	1 - 5 mm	> 5 mm			< 0.1 mm	0.1 - 1 mm	< 0.1 mm	0.1 - 1 mm	< 0.1 mm	< 0.1 mm	none	< 0.1 mm	< 0.1 mm	none
Rating		6	5	4	1	0			5	4	5	4	5	5	6	5	5	6
Roughness		Very rough	Rough	Slightly rough	Smooth	Slickensided			rough	slightly rough	rough	slightly rough	rough	rough	very rough	rough	rough	very rough
Rating		6	5	3	1	0			5	3	5	3	5	5	6	5	5	6
Infilling (gouge)		None	Hard filling < 5 mm	Hard filling > 5 mm	Soft filling < 5 mm	Soft filling > 5 mm			None	Hard filling < 5 mm	None	Hard filling < 5 mm	None	Hard filling < 5 mm	None	Hard filling < 5 mm	None	None
Rating		6	4	2	2	0			6	4	6	4	6	4	6	4	6	6
Weathering		Unweathered	Slightly weathered	Moderately weathered	Highly weathered	Decomposed			Slightly weathered	Slightly weathered	Slightly weathered	Slightly weathered	Slightly weathered	Slightly weathered	Unweathered	Unweathered	Unweathered	Unweathered
Rating		6	5	3	1	0			5	5	5	5	5	5	6	6	6	6
Condition of discontinuities (see following guidelines)		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Slickensided surfaces or Gouge < 5 mm thick or Separation 1-5 mm Continuous	Soft gouge >5 mm thick or Separation > 5 mm Continuous			Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Very rough surfaces Not continuous No separation Unweathered wall rock	Very rough surfaces Not continuous No separation Unweathered wall rock
Rating		30	25	20	10	0			27	20	27	20	27	23	30	26	28	30
5 Ground water	Inflow per 10 m tunnel length (l/m)	None	< 10	10 - 25	25 - 125	> 125			None	None	None	None	None	None	None	None	None	None
	(Joint water pressure / Major principal σ)	0	< 0.1	0.1 - 0.2	0.2 - 0.5	> 0.5			0	0	0	0	0	0	0	0	0	0
	General conditions	Completely dry	Damp	Wet	Dripping	Flowing			Completely dry	Completely dry	Completely dry	Completely dry	Completely dry	Completely dry	Completely dry	Completely dry	Completely dry	Completely dry
Rating		15	10	7	4	0			15	15	15	15	15	15	15	15	15	15
B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS		RATING ADJUSTMENT GUIDELINES																
		Strike perpendicular to tunnel axis		Strike parallel to tunnel axis														
		Drive with dip - Dip 45 - 90°	Drive with dip - Dip 20 - 45°	Dip 45 -90°		Dip 20 -45°												
		Very favourable	Favourable	Very unfavourable		Fair												
		Drive against dip - Dip 45 90°	Drive against dip - Dip 20-45°	Dip 0-20 -irrespective of strike*														
		Fair	Unfavourable	Fair														
Strike and dip orientations		Very favourable	Favourable	Fair	Unfavourable	Very Unfavourable			Very favourable	Very favourable	Very favourable	Very favourable	Very favourable	Very favourable	Very favourable	Very favourable	Very favourable	Very favourable
Ratings	Tunnels & mines	0	-2	-5	-10	-12												
	Foundations	0	-2	-7	-15	-25			0	0	0	0	0	0	0	0	0	0
	Slopes	0	-5	-25	-50													
C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS																		
Rating		100 ← 81	80 ← 61	60 ← 41	40 ← 21	< 21			76	63	79	63	79	75	84	83	85	89
Class number		I	II	III	IV	V			II	II	II	II	II	II	I	I	I	I
Description		Very good rock	Good rock	Fair rock	Poor rock	Very poor rock			good	good	good	good	good	good	very good	very good	very good	very good

D. MEANING OF ROCK CLASSES (Typical Engineering Properties)							
Class number	I	II	III	IV	V	II	I
Average stand-up time	20 yrs for 15 m span	1 year for 10 m span	1 week for 5 m span	10 hrs for 2.5 m span	30 min for 1 m span	1 year for 10 m span	20 yrs for 15 m span
Cohesion of rock mass (kPa)	> 400	300 - 400	200 - 300	100 - 200	< 100	300 - 400 kPa (6.3 - 8.4 ksf)	> 400 kPa (>8.4 ksf)
Friction angle of rock mass (deg)	> 45	35 - 45	25 - 35	15 - 25	< 15	35 - 45	> 45

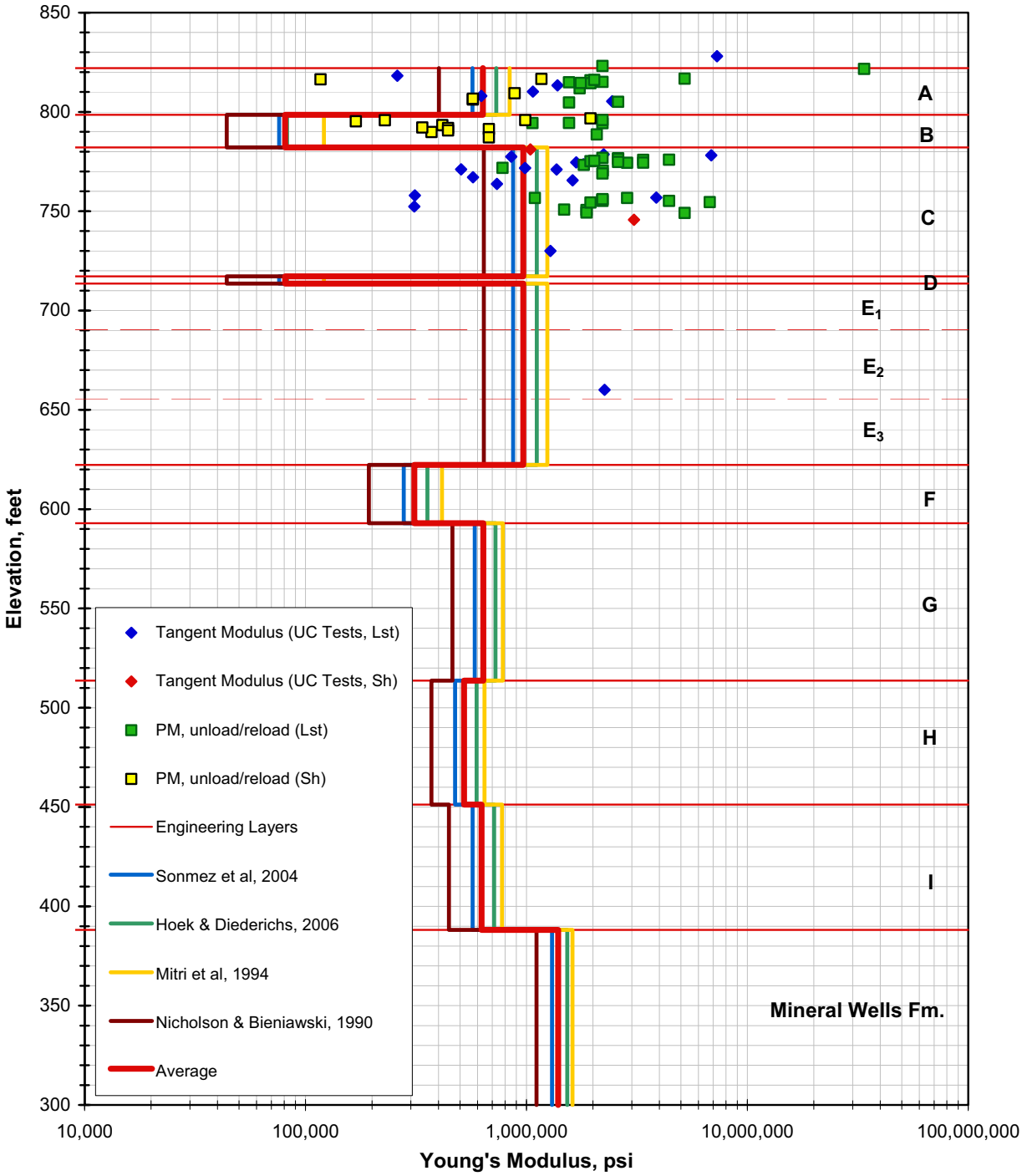
Rock Mass Rating System & Project Parameters

FIGURE 20



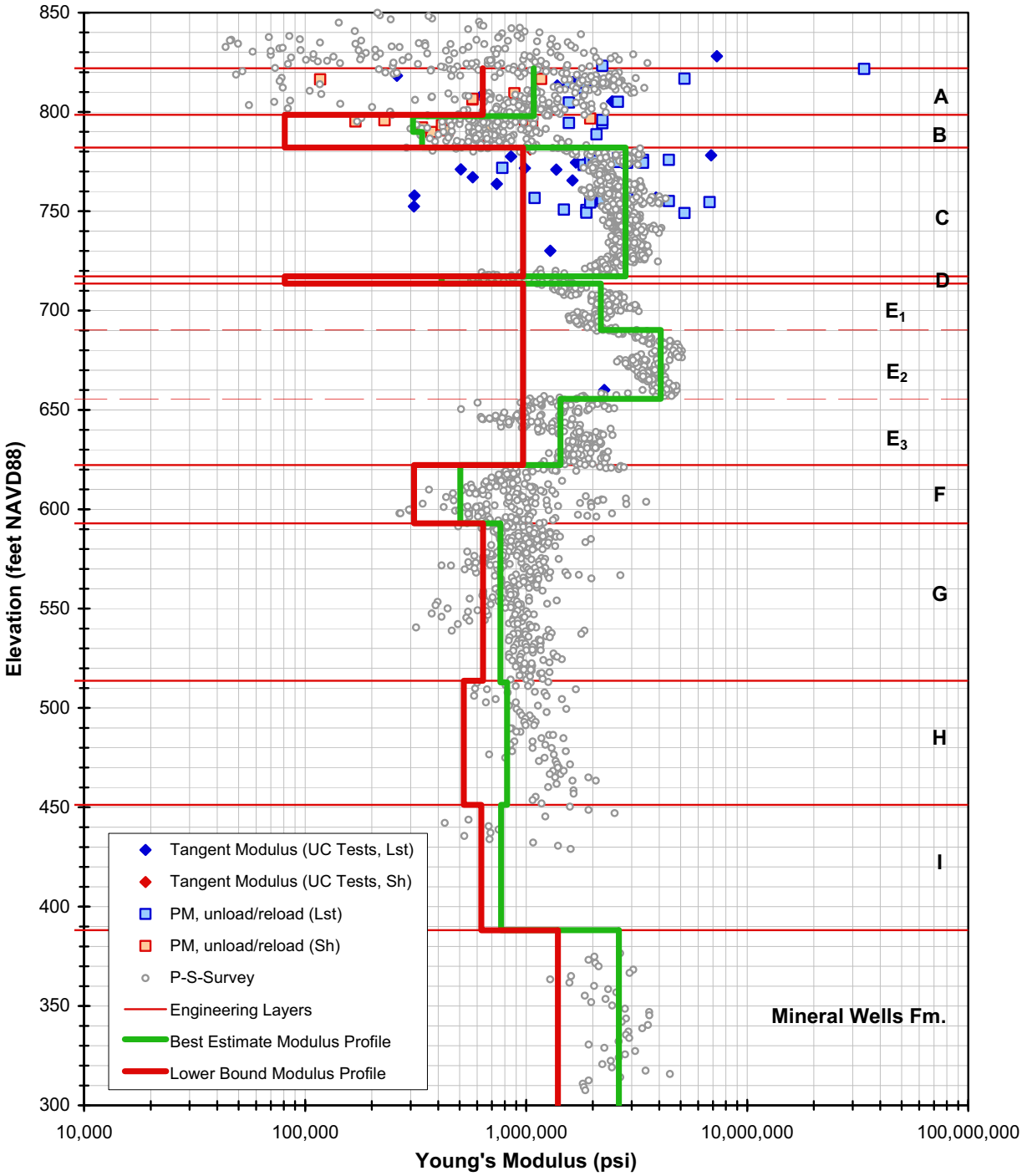
GSI Chart
(after Marinos and Hoek 2000)

FIGURE 21



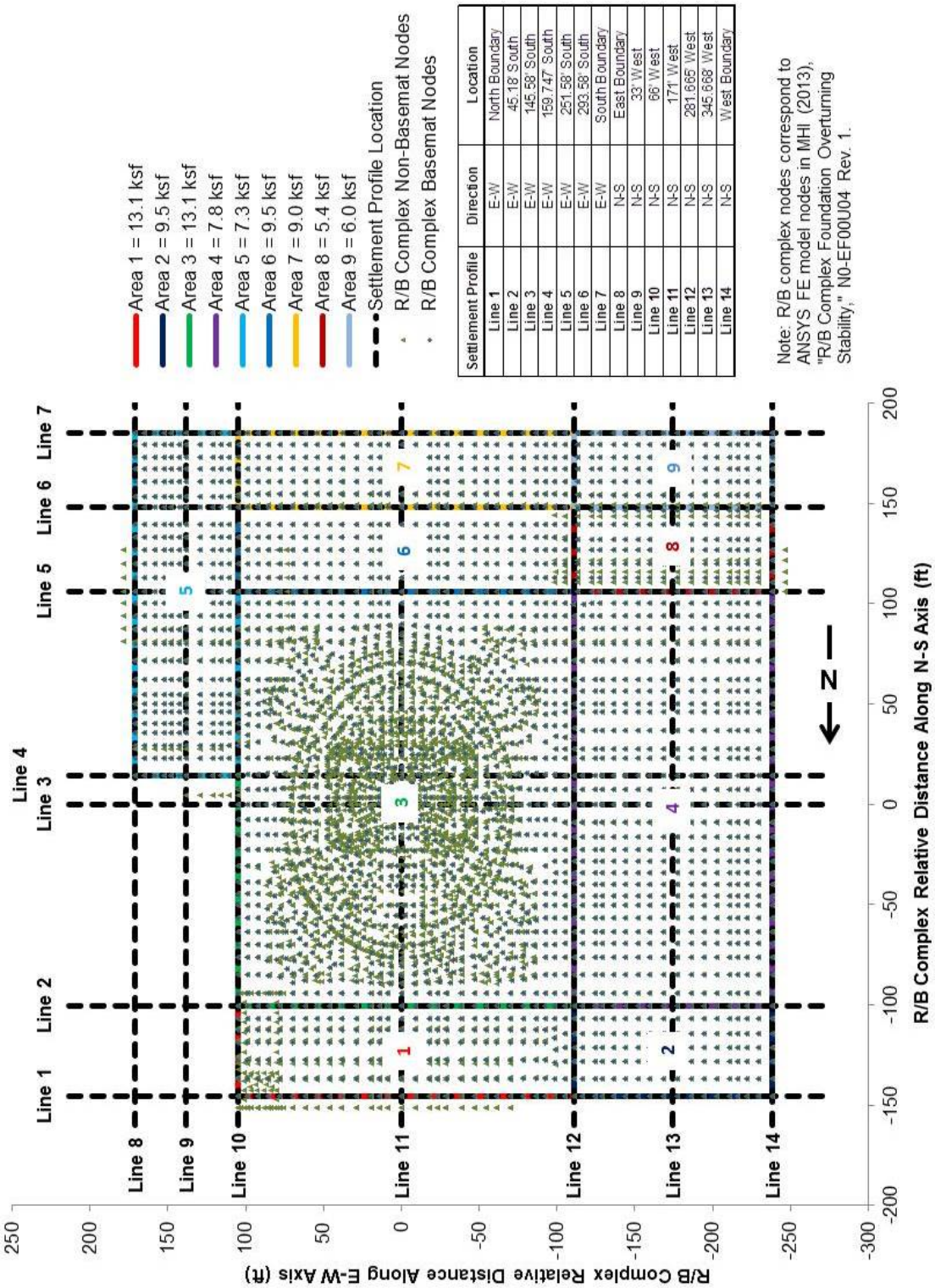
Estimated Range of Rock Mass Modulus (E_{rm}) vs. Elevation

FIGURE 22



Best Estimate & Lower Bound Modulus Models vs. Elevation

FIGURE 23

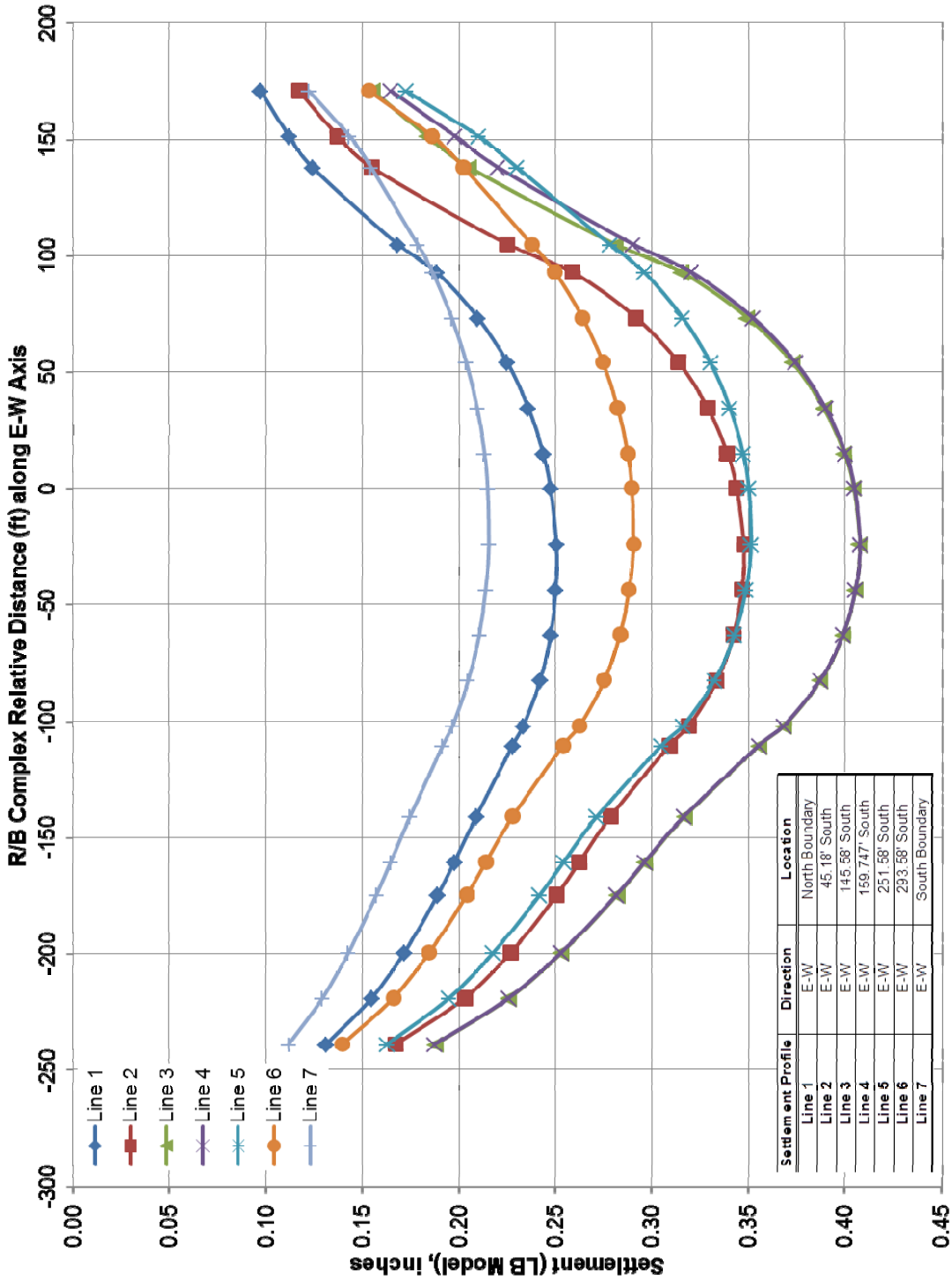


Settlement Profile	Direction	Location
Line 1	E-W	North Boundary
Line 2	E-W	45.18' South
Line 3	E-W	145.58' South
Line 4	E-W	159.747' South
Line 5	E-W	251.58' South
Line 6	E-W	293.58' South
Line 7	E-W	South Boundary
Line 8	N-S	East Boundary
Line 9	N-S	33' West
Line 10	N-S	66' West
Line 11	N-S	171' West
Line 12	N-S	281.665' West
Line 13	N-S	345.668' West
Line 14	N-S	West Boundary

Note: R/B complex nodes correspond to ANSYS FE model nodes in MHI (2013), "R/B Complex Foundation Overturning Stability," N0-EF00U04 Rev. 1.

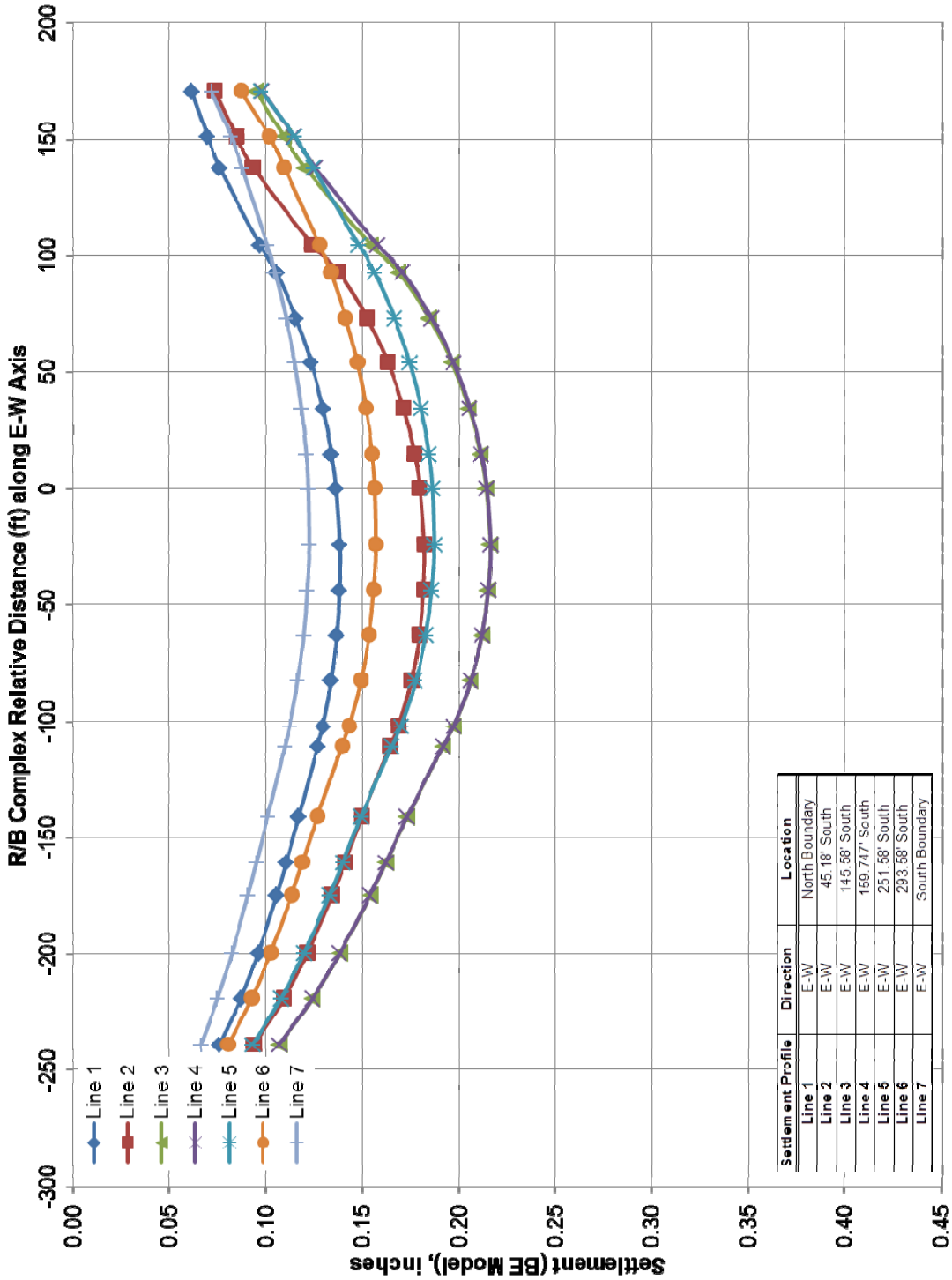
R/B Complex Simplified Loading for Settlement Calculation

FIGURE 24



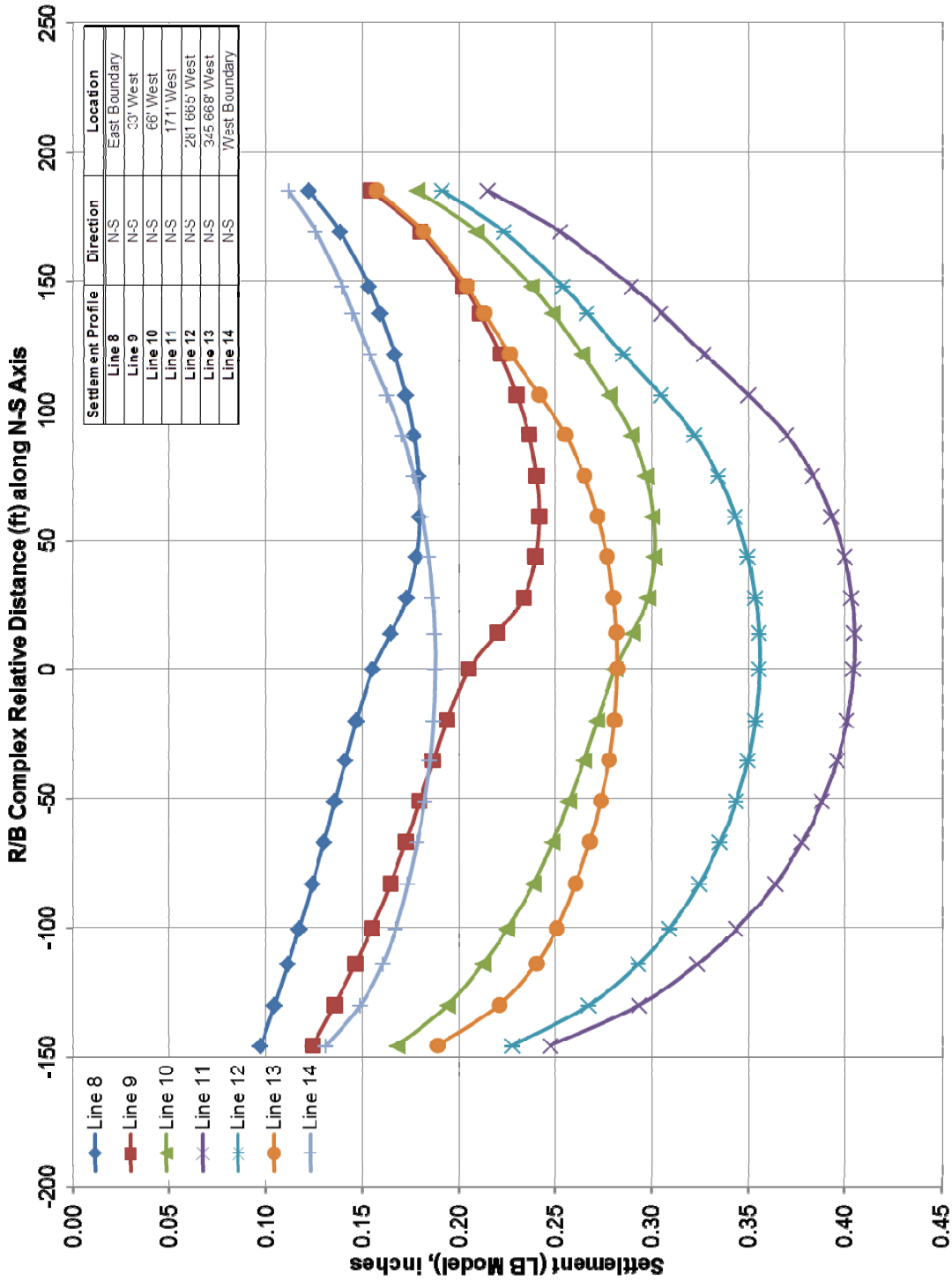
R/B Complex Settlement Estimates Along East-West Axis
LB Model

FIGURE 25



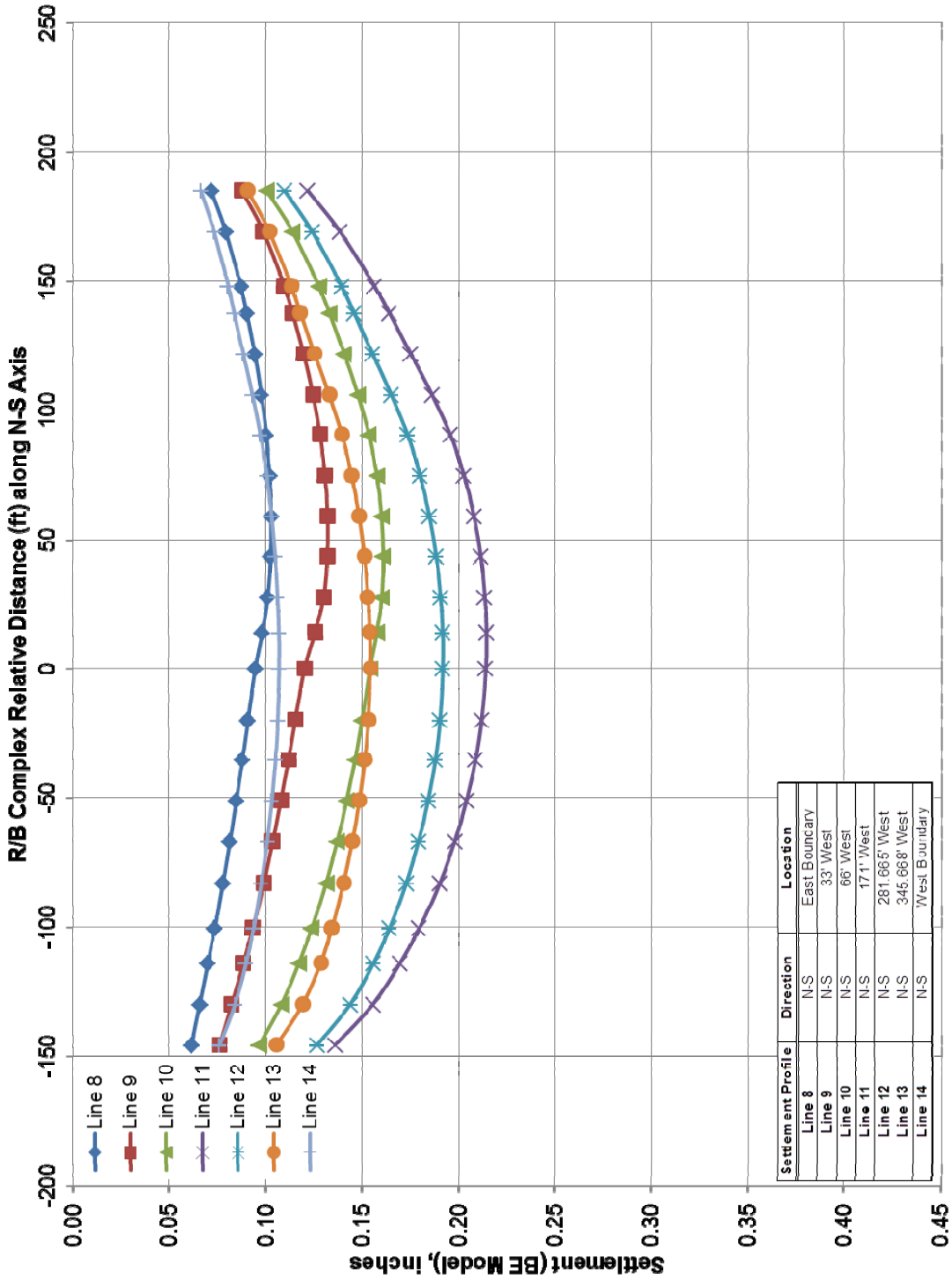
R/B Complex Settlement Estimates Along East-West Axis
BE Model

FIGURE 26



R/B Complex Settlement Estimates Along North-South Axis
LB Model

FIGURE 27



R/B Complex Settlement Estimates Along North-South Axis
BE Model

FIGURE 28

APPENDIX A

Settlement Calculations

Layered Method Using Best Estimated Rock Modulus (BERM) Model (Excel)
Pages 2 through 9
Layered Method Using Lower Bound Rock Modulus (LBRM) Model (Excel)
Pages 10 through 17
Non-Layered Method Using Best Estimated Rock Modulus (BERM) Model (Excel)
Pages 18 through 26
Non-Layered Method Using Lower Bound Rock Modulus (LBRM) Model (Excel)
Pages 27 through 35
Layered Method Using Best Estimated Rock Modulus (BERM) Model (Mathcad)
Pages 36 through 43
Layered Method Using Lower Bound Rock Modulus (LBRM) Model (Mathcad)
Pages 44 through 51
Non-Layered Method Using Best Estimated Rock Modulus (BERM) Model (Mathcad)
Pages 52 through 57
Non-Layered Method Using Lower Bound Rock Modulus (LBRM) Model (Mathcad)
Pages 58 through 63

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, BERM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

SUMMARY OF INPUT

Number of Loaded Areas= 7 **Number of Soil Layers=** 25 **Number of Settlement Points=** 22

Poisson's Ratio= 0.30 **Stress distribution code=** 1 **Depth of Grondwater Table=** 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	112.7	679.5	459.7	679.5	459.7	344.9	112.7	344.9
2	4.9	40.0	0.0	939.6	267.0	939.6	267.0	779.6	0.0	779.6
3	4.9	40.0	333.1	939.6	600.1	939.6	600.1	779.6	333.1	779.6
4	4.0	40.0	100.2	341.7	198.2	341.7	198.2	246.7	100.2	246.7
5	4.0	40.0	498.7	341.7	596.7	341.7	596.7	246.7	498.7	246.7
6	13.1	40.0	459.7	519.0	525.7	519.0	525.7	344.9	459.7	344.9
7	10.0	40.0	198.2	342.7	463.7	342.7	463.7	0.0	198.2	0.0

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	0.0	940.6	2	267.0	940.6
3	267.0	780.6	4	0.0	780.6
5	133.5	860.6	6	600.1	940.6
7	333.1	780.6	8	466.6	860.6
9	112.7	680.5	10	286.2	680.5
11	459.7	680.5	12	459.7	513.2
13	459.7	345.9	14	286.2	345.9
15	112.7	345.9	16	112.7	513.2
17	286.2	513.2	18	525.7	520.0
19	525.7	345.9	20	492.7	433.0
21	149.2	295.2	22	547.7	295.2

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
19	417.50	33.00	110901	20	463.00	58.00	378268
21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	1.07	1.07	1.38	1.38	4.90	1.07	1.38	4.90	2.86	5.72	2.86	11.82	9.56	10.44	4.64	6.55	13.10	2.87	4.71	13.03	4.01	3.98
70.00	1.17	1.21	1.37	1.28	4.80	1.17	1.37	4.80	3.16	6.27	3.16	10.48	9.32	11.10	4.63	6.54	13.06	3.23	4.92	12.02	4.14	3.72
92.50	1.18	1.32	1.63	1.27	4.50	1.18	1.63	4.50	3.28	6.39	3.30	9.80	9.04	11.12	4.56	6.49	12.90	3.55	4.91	10.46	4.43	3.31
107.00	1.18	1.40	1.88	1.28	4.23	1.18	1.87	4.22	3.36	6.42	3.39	9.41	8.80	11.01	4.55	6.43	12.72	3.75	4.90	9.61	4.61	3.17
120.50	1.17	1.46	2.13	1.29	3.96	1.17	2.11	3.95	3.43	6.42	3.48	9.05	8.56	10.85	4.55	6.36	12.48	3.92	4.90	8.94	4.74	3.13
149.00	1.14	1.57	2.62	1.33	3.43	1.14	2.60	3.40	3.56	6.34	3.66	8.35	8.03	10.37	4.55	6.16	11.82	4.19	4.86	7.87	4.91	3.20
183.00	1.10	1.64	3.05	1.39	2.93	1.09	3.02	2.90	3.64	6.14	3.80	7.60	7.42	9.66	4.53	5.85	10.83	4.33	4.77	6.98	4.97	3.35
214.50	1.06	1.68	3.27	1.44	2.62	1.05	3.24	2.57	3.65	5.88	3.85	6.98	6.89	8.95	4.48	5.54	9.85	4.33	4.64	6.36	4.91	3.45
239.00	1.04	1.69	3.35	1.48	2.44	1.03	3.31	2.40	3.61	5.64	3.84	6.54	6.50	8.38	4.40	5.29	9.10	4.28	4.52	5.97	4.82	3.48
264.00	1.03	1.69	3.36	1.52	2.31	1.01	3.33	2.27	3.55	5.37	3.79	6.13	6.12	7.82	4.31	5.03	8.37	4.19	4.39	5.61	4.70	3.48
294.00	1.01	1.69	3.32	1.55	2.19	1.00	3.30	2.15	3.45	5.05	3.70	5.67	5.69	7.17	4.17	4.74	7.57	4.06	4.21	5.23	4.52	3.44
324.00	1.01	1.68	3.24	1.57	2.10	1.00	3.22	2.07	3.33	4.73	3.58	5.26	5.29	6.57	4.01	4.45	6.85	3.90	4.03	4.88	4.32	3.37
355.00	1.01	1.66	3.13	1.58	2.03	0.99	3.11	1.99	3.20	4.42	3.44	4.87	4.91	6.00	3.83	4.18	6.20	3.72	3.83	4.55	4.10	3.26
386.00	1.01	1.64	3.00	1.58	1.96	1.00	2.98	1.93	3.05	4.12	3.29	4.51	4.55	5.48	3.65	3.92	5.62	3.55	3.64	4.25	3.88	3.14
417.50	1.01	1.61	2.86	1.57	1.89	1.00	2.85	1.87	2.91	3.83	3.13	4.18	4.22	5.00	3.46	3.67	5.10	3.36	3.44	3.96	3.65	3.01
463.00	1.00	1.56	2.65	1.54	1.80	1.00	2.65	1.79	2.70	3.46	2.90	3.75	3.78	4.40	3.19	3.34	4.46	3.10	3.16	3.58	3.34	2.81
542.00	0.99	1.46	2.32	1.47	1.65	0.99	2.32	1.65	2.36	2.90	2.52	3.12	3.14	3.55	2.75	2.83	3.59	2.69	2.72	3.01	2.85	2.47
642.00	0.95	1.32	1.95	1.35	1.46	0.96	1.95	1.47	1.99	2.34	2.11	2.51	2.51	2.77	2.27	2.32	2.79	2.23	2.25	2.44	2.33	2.08
742.00	0.90	1.18	1.64	1.21	1.29	0.91	1.65	1.30	1.68	1.92	1.77	2.04	2.04	2.20	1.89	1.92	2.22	1.86	1.87	2.00	1.92	1.75
842.00	0.84	1.05	1.40	1.08	1.14	0.85	1.40	1.15	1.43	1.59	1.49	1.68	1.68	1.79	1.58	1.60	1.80	1.56	1.56	1.65	1.60	1.48
942.00	0.77	0.93	1.20	0.97	1.00	0.78	1.20	1.01	1.22	1.34	1.27	1.41	1.40	1.47	1.33	1.34	1.48	1.32	1.32	1.38	1.34	1.26

Appendix A

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
12	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.03	0.02	0.03	0.03	0.04	0.02	0.02	0.04	0.02	0.02	0.03	0.02	0.02
13	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
14	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01
15	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01
16	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
17	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
18	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
19	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
21	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
22	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.05**	**0.07**	**0.12**	**0.06**	**0.10**	**0.05**	**0.12**	**0.10**	**0.13**	**0.19**	**0.14**	**0.22**	**0.22**	**0.27**	**0.16**	**0.18**	**0.29**	**0.15**	**0.16**	**0.21**	**0.17**	**0.13**

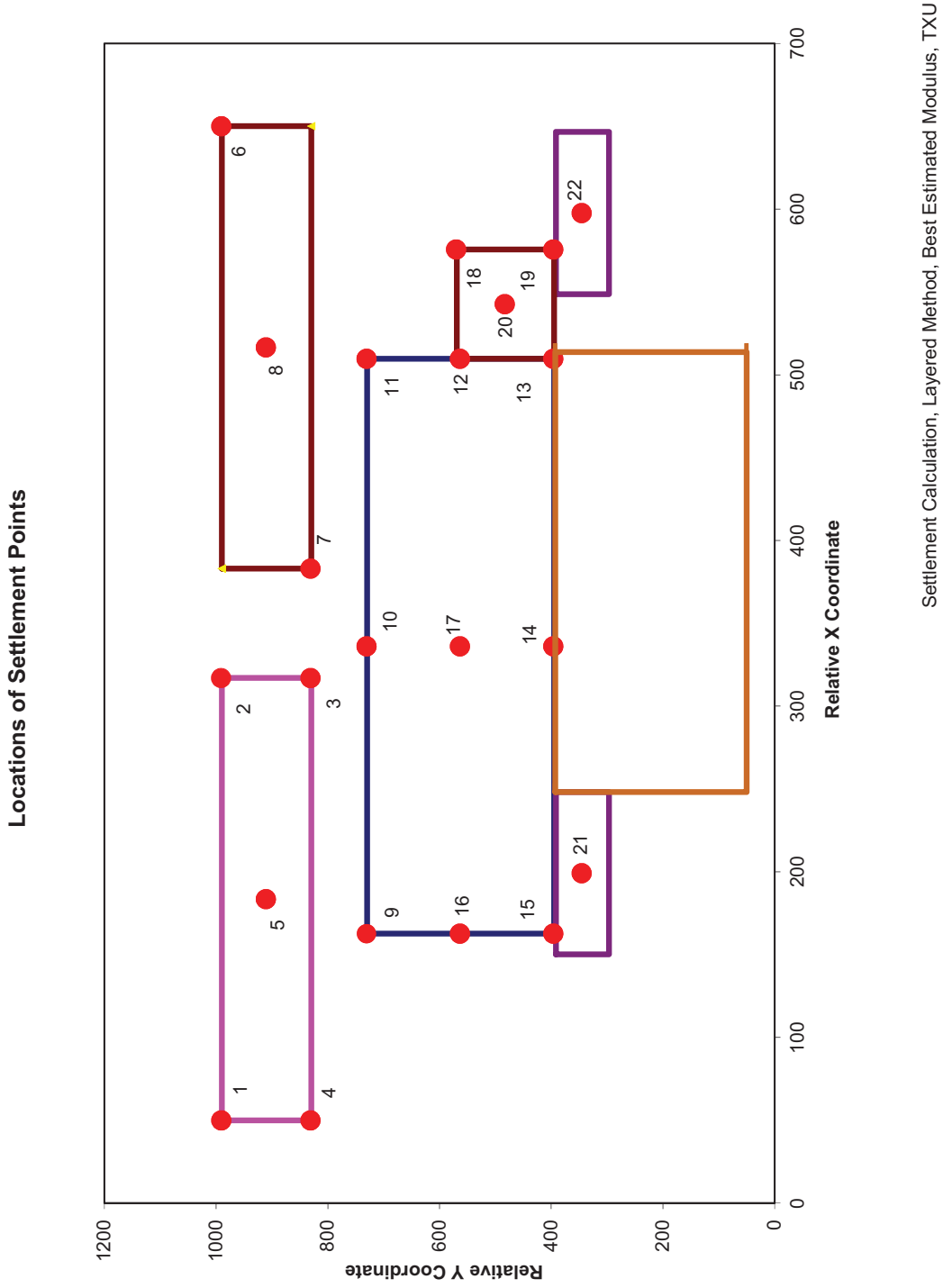
Appendix A

Settlement Calculation, Best Estimated Rock Modulus, TXU

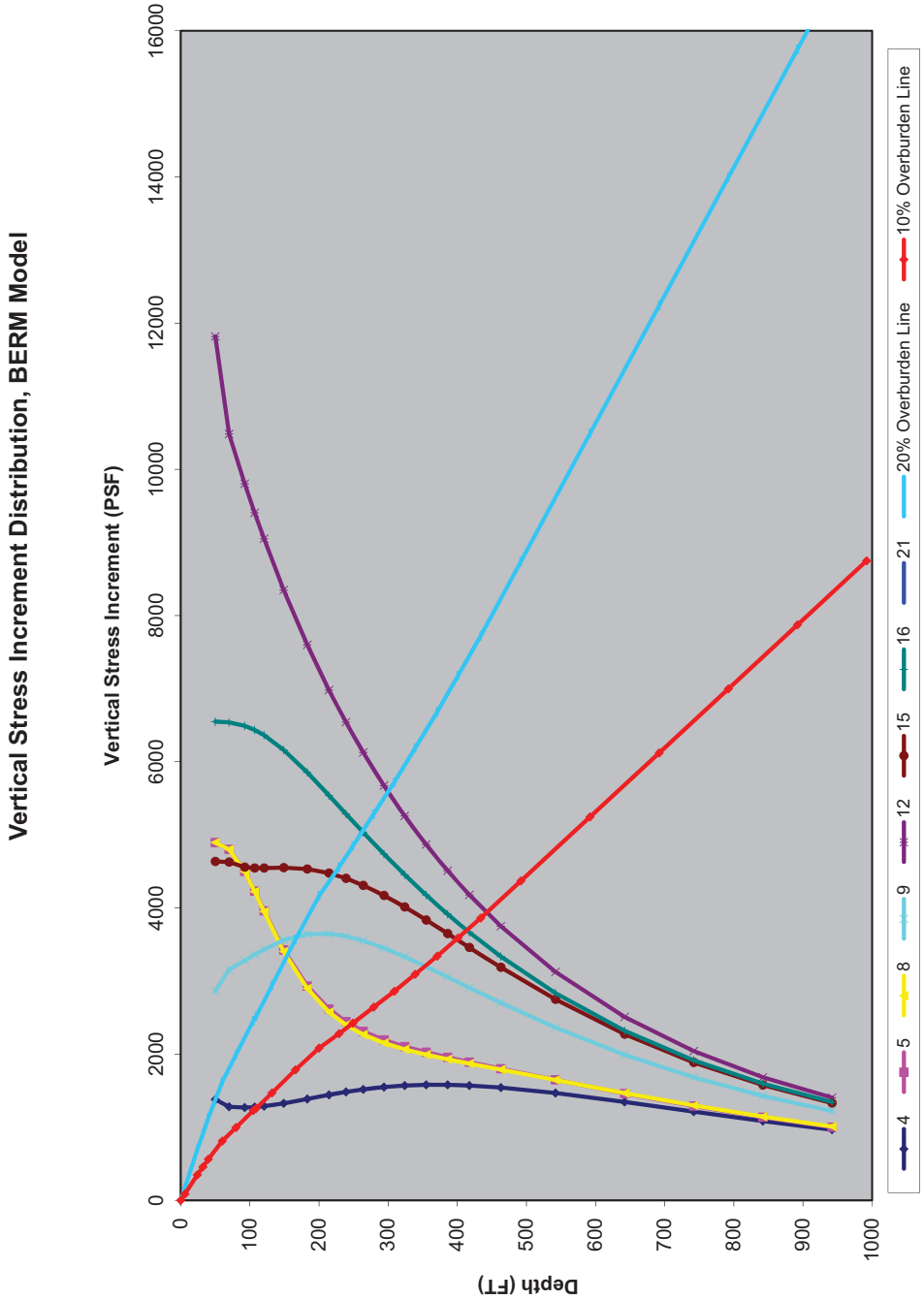
SUMMARY OF SETTLEMENT

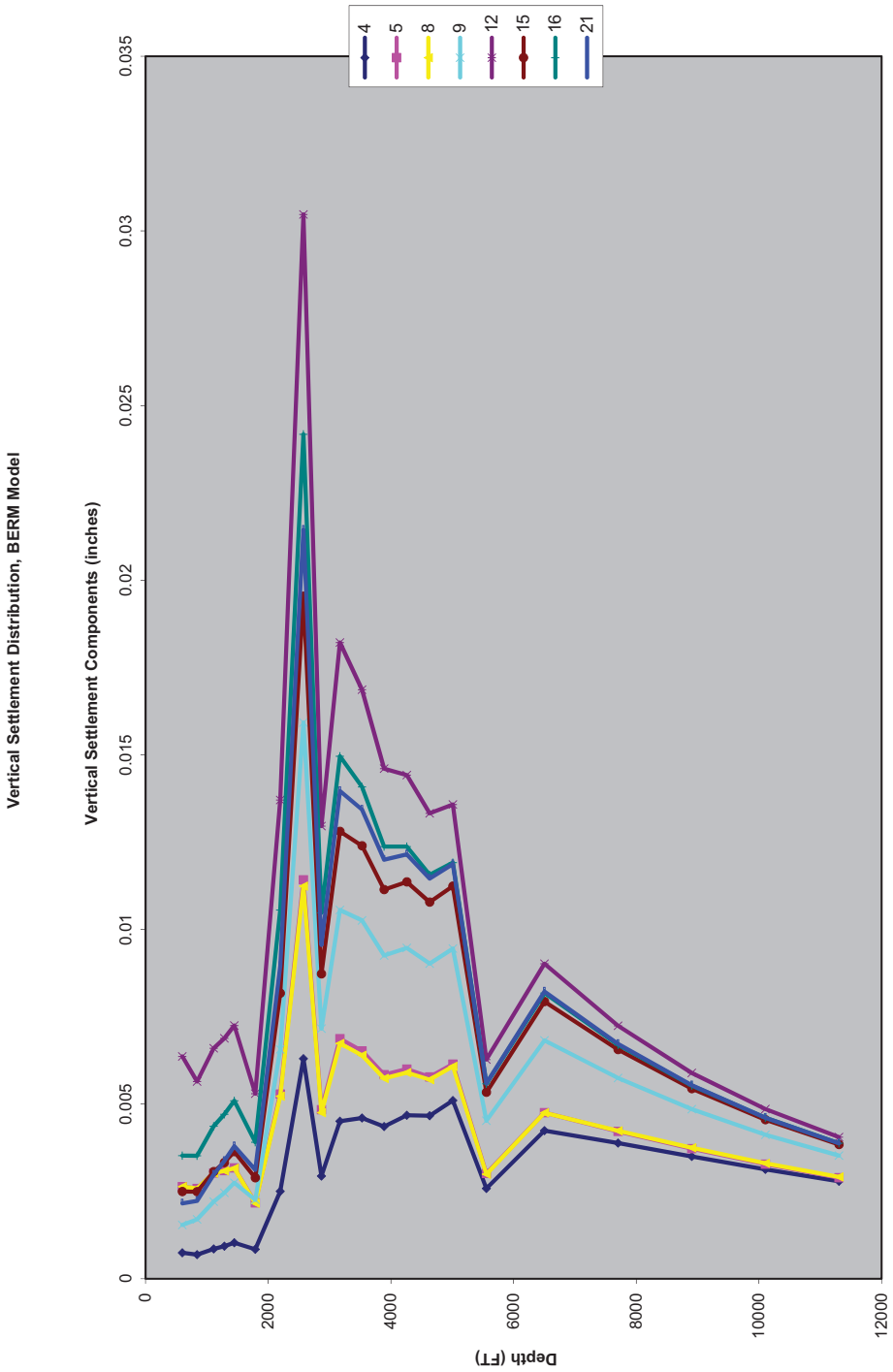
Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	0.0	940.6	**0.05**	**2**	267.0	940.6	**0.07**
3	267.0	780.6	**0.12**	**4**	0.0	780.6	**0.06**
5	133.5	860.6	**0.10**	**6**	600.1	940.6	**0.05**
7	333.1	780.6	**0.12**	**8**	466.6	860.6	**0.10**
9	112.7	680.5	**0.13**	**10**	286.2	680.5	**0.19**
11	459.7	680.5	**0.14**	**12**	459.7	513.2	**0.22**
13	459.7	345.9	**0.22**	**14**	286.2	345.9	**0.27**
15	112.7	345.9	**0.16**	**16**	112.7	513.2	**0.18**
17	286.2	513.2	**0.29**	**18**	525.7	520.0	**0.15**
19	525.7	345.9	**0.16**	**20**	492.7	433.0	**0.21**
21	149.2	295.2	**0.17**	**22**	547.7	295.2	**0.13**

Appendix A



Settlement Calculation, Layered Method, Best Estimated Modulus, TXU


Vertical Stress Increment Distribution, BERM Model
Vertical Stress Increment (PSF)
0
2000
4000
6000
8000
10000
12000
14000
16000
Depth (FT)
0
100
200
300
400
500
600
700
800
900
1000
4
5
8
9
12
15
16
21
20% Overburden Line
10% Overburden Line


Vertical Settlement Distribution, BERM Model
Vertical Settlement Components (inches)
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
Depth (FT)
0
2000
4000
6000
8000
10000
12000
4
5
8
9
12
15
16
21

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, LBRM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

SUMMARY OF INPUT

Number of Loaded Areas= 7 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	112.7	679.5	459.7	679.5	459.7	344.9	112.7	344.9
2	4.9	40.0	0.0	939.6	267.0	939.6	267.0	779.6	0.0	779.6
3	4.9	40.0	333.1	939.6	600.1	939.6	600.1	779.6	333.1	779.6
4	4.0	40.0	100.2	341.7	198.2	341.7	198.2	246.7	100.2	246.7
5	4.0	40.0	498.7	341.7	596.7	341.7	596.7	246.7	498.7	246.7
6	13.1	40.0	459.7	519.0	525.7	519.0	525.7	344.9	459.7	344.9
7	10.0	40.0	198.2	342.7	463.7	342.7	463.7	0.0	198.2	0.0

SETTLEMENT POINT COORDINATES

ID	X	Y	ID	X	Y
1	0.0	940.6	2	267.0	940.6
3	267.0	780.6	4	0.0	780.6
5	133.5	860.6	6	600.1	940.6
7	333.1	780.6	8	466.6	860.6
9	112.7	680.5	10	286.2	680.5
11	459.7	680.5	12	459.7	513.2
13	459.7	345.9	14	286.2	345.9
15	112.7	345.9	16	112.7	513.2
17	286.2	513.2	18	525.7	520.0
19	525.7	345.9	20	492.7	433.0
21	149.2	295.2	22	547.7	295.2

LAYER COMPRESSIBILITY

LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	91508	2	15.00	18.00	91508
3	28.00	8.00	11650	4	36.00	8.00	11650
5	50.00	20.00	139212	6	70.00	20.00	139212
7	92.50	25.00	139212	8	107.00	4.00	11650
9	120.50	23.00	139212	10	149.00	34.00	139212
11	183.00	34.00	139212	12	214.50	29.00	44754
13	239.00	20.00	91866	14	264.00	30.00	91866
15	294.00	30.00	91866	16	324.00	30.00	75174
17	355.00	32.00	75174	18	386.00	30.00	90209
19	417.50	33.00	90209	20	463.00	58.00	200298
21	542.00	100.00	200298	22	642.00	100.00	200298
23	742.00	100.00	200298	24	842.00	100.00	200298
25	942.00	100.00	200298				

Settlement Calculation, Low Bound Estimated Rock Modulus, TXU

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Depth (FT)	Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	1.07	1.07	1.38	1.38	4.90	1.07	1.38	4.90	2.86	5.72	2.86	11.82	9.56	10.44	4.64	6.55	13.10	2.87	4.71	13.03	4.01	3.98
70.00	1.17	1.21	1.37	1.28	4.80	1.17	1.37	4.80	3.16	6.27	3.16	10.48	9.32	11.10	4.63	6.54	13.06	3.23	4.92	12.02	4.14	3.72
92.50	1.18	1.32	1.63	1.27	4.50	1.18	1.63	4.50	3.28	6.39	3.30	9.80	9.04	11.12	4.56	6.49	12.90	3.55	4.91	10.46	4.43	3.31
107.00	1.18	1.40	1.88	1.28	4.23	1.18	1.87	4.22	3.36	6.42	3.39	9.41	8.80	11.01	4.55	6.43	12.72	3.75	4.90	9.61	4.61	3.17
120.50	1.17	1.46	2.13	1.29	3.96	1.17	2.11	3.95	3.43	6.42	3.48	9.05	8.56	10.85	4.55	6.36	12.48	3.92	4.90	8.94	4.74	3.13
149.00	1.14	1.57	2.62	1.33	3.43	1.14	2.60	3.40	3.56	6.34	3.66	8.35	8.03	10.37	4.55	6.16	11.82	4.19	4.86	7.87	4.91	3.20
183.00	1.10	1.64	3.05	1.39	2.93	1.09	3.02	2.90	3.64	6.14	3.80	7.60	7.42	9.66	4.53	5.85	10.83	4.33	4.77	6.98	4.97	3.35
214.50	1.06	1.68	3.27	1.44	2.62	1.05	3.24	2.57	3.65	5.88	3.85	6.98	6.89	8.95	4.48	5.54	9.85	4.33	4.64	6.36	4.91	3.45
239.00	1.04	1.69	3.35	1.48	2.44	1.03	3.31	2.40	3.61	5.64	3.84	6.54	6.50	8.38	4.40	5.29	9.10	4.28	4.52	5.97	4.82	3.48
264.00	1.03	1.69	3.36	1.52	2.31	1.01	3.33	2.27	3.55	5.37	3.79	6.13	6.12	7.82	4.31	5.03	8.37	4.19	4.39	5.61	4.70	3.48
294.00	1.01	1.69	3.32	1.55	2.19	1.00	3.30	2.15	3.45	5.05	3.70	5.67	5.69	7.17	4.17	4.74	7.57	4.06	4.21	5.23	4.52	3.44
324.00	1.01	1.68	3.24	1.57	2.10	1.00	3.22	2.07	3.33	4.73	3.58	5.26	5.29	6.57	4.01	4.45	6.85	3.90	4.03	4.88	4.32	3.37
355.00	1.01	1.66	3.13	1.58	2.03	0.99	3.11	1.99	3.20	4.42	3.44	4.87	4.91	6.00	3.83	4.18	6.20	3.72	3.83	4.55	4.10	3.26
386.00	1.01	1.64	3.00	1.58	1.96	1.00	2.98	1.93	3.05	4.12	3.29	4.51	4.55	5.48	3.65	3.92	5.62	3.55	3.64	4.25	3.88	3.14
417.50	1.01	1.61	2.86	1.57	1.89	1.00	2.85	1.87	2.91	3.83	3.13	4.18	4.22	5.00	3.46	3.67	5.10	3.36	3.44	3.96	3.65	3.01
463.00	1.00	1.56	2.65	1.54	1.80	1.00	2.65	1.79	2.70	3.46	2.90	3.75	3.78	4.40	3.19	3.34	4.46	3.10	3.16	3.58	3.34	2.81
542.00	0.99	1.46	2.32	1.47	1.65	0.99	2.32	1.65	2.36	2.90	2.52	3.12	3.14	3.55	2.75	2.83	3.59	2.69	2.72	3.01	2.85	2.47
642.00	0.95	1.32	1.95	1.35	1.46	0.96	1.95	1.47	1.99	2.34	2.11	2.51	2.51	2.77	2.27	2.32	2.79	2.23	2.25	2.44	2.33	2.08
742.00	0.90	1.18	1.64	1.21	1.29	0.91	1.65	1.30	1.68	1.92	1.77	2.04	2.04	2.20	1.89	1.92	2.22	1.86	1.87	2.00	1.92	1.75
842.00	0.84	1.05	1.40	1.08	1.14	0.85	1.40	1.15	1.43	1.59	1.49	1.68	1.68	1.79	1.58	1.60	1.80	1.56	1.56	1.65	1.60	1.48
942.00	0.77	0.93	1.20	0.97	1.00	0.78	1.20	1.01	1.22	1.34	1.27	1.41	1.40	1.47	1.33	1.34	1.48	1.32	1.32	1.38	1.34	1.26

Appendix A

SETTLEMENT DISTRIBUTION (INCHES)

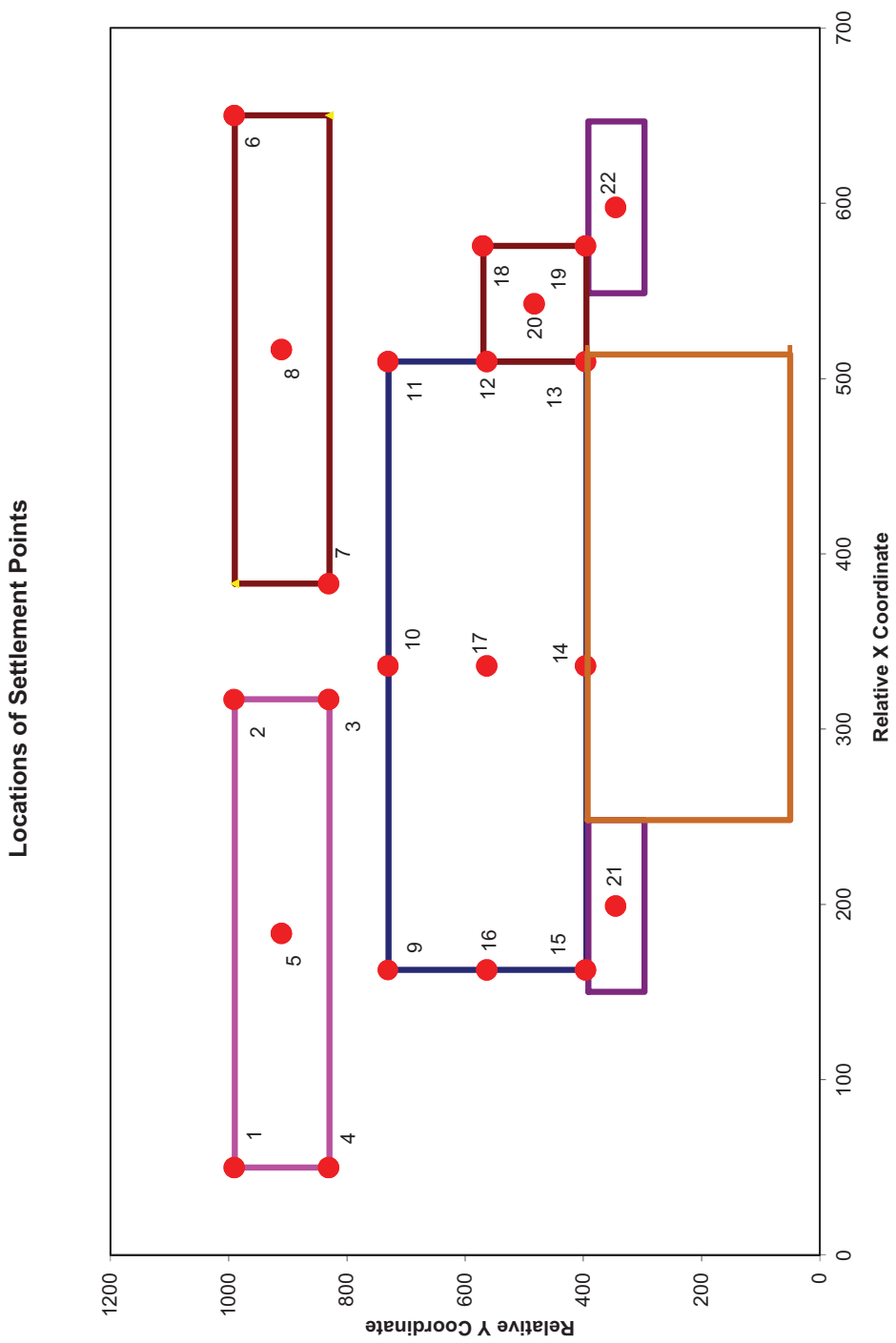
Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.02	0.01	0.02	0.01	0.01	0.02	0.00	0.01	0.02	0.01	0.01
6	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.02	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01
7	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.03	0.01	0.01	0.02	0.01	0.01
8	0.00	0.01	0.01	0.00	0.02	0.00	0.01	0.02	0.01	0.02	0.01	0.04	0.03	0.04	0.02	0.02	0.05	0.01	0.02	0.04	0.02	0.01
9	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01
10	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.03	0.01	0.02	0.03	0.01	0.01	0.02	0.01	0.01
11	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.03	0.01	0.02	0.03	0.01	0.01	0.02	0.01	0.01
12	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.02	0.03	0.04	0.03	0.05	0.05	0.06	0.03	0.04	0.07	0.03	0.03	0.05	0.03	0.02
13	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
14	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.03	0.02	0.02	0.03	0.01	0.02	0.02	0.02	0.01
15	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.03	0.01	0.02	0.03	0.01	0.02	0.02	0.02	0.01
16	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.01
17	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02
18	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01
19	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01
20	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.02	0.02	0.01
22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
23	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
24	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
25	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total	**0.08**	**0.12**	**0.19**	**0.11**	**0.18**	**0.08**	**0.19**	**0.18**	**0.22**	**0.33**	**0.23**	**0.40**	**0.39**	**0.48**	**0.27**	**0.32**	**0.52**	**0.25**	**0.28**	**0.39**	**0.28**	**0.22**

Appendix A

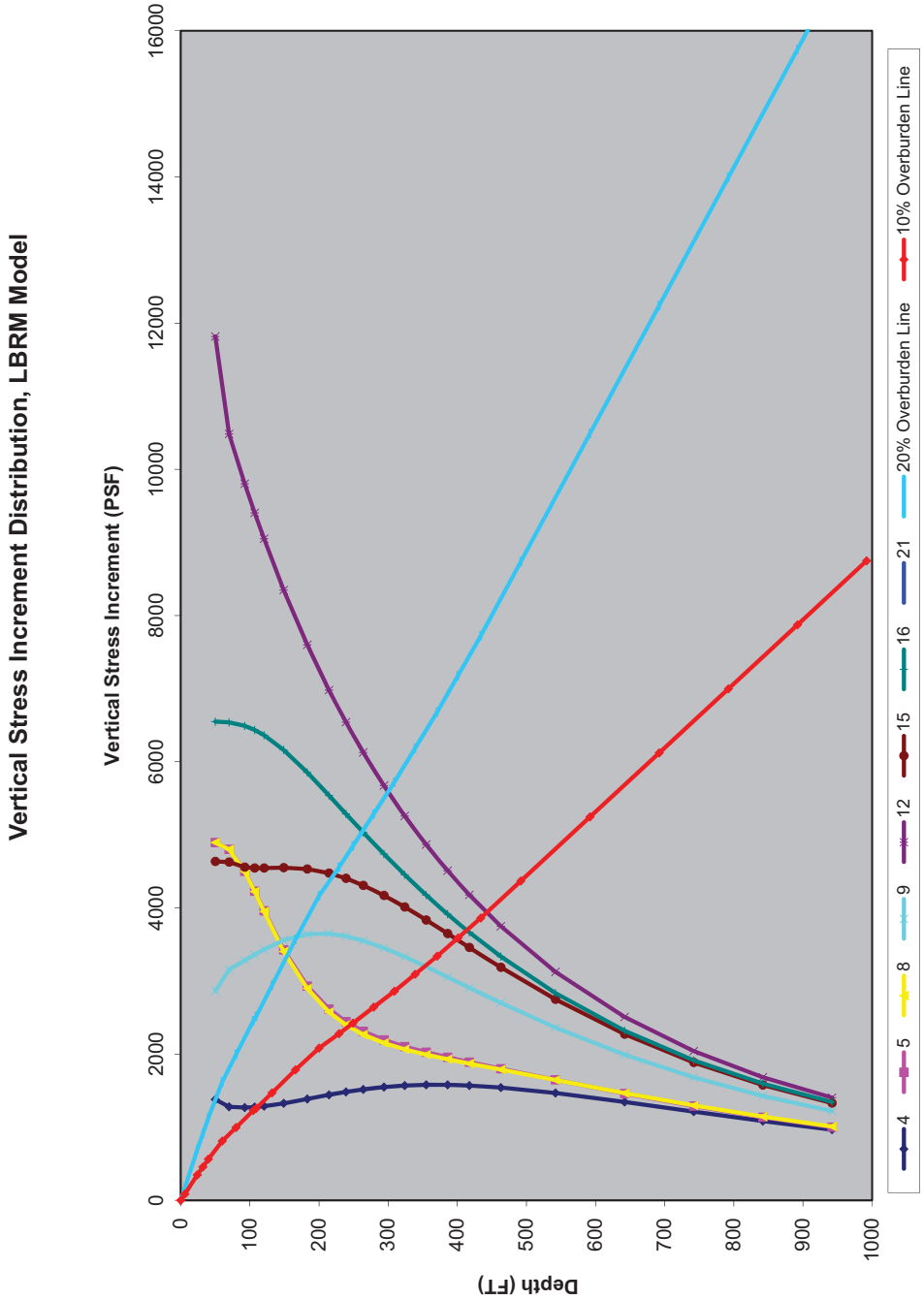
Settlement Calculation, Low Bound Estimated Rock Modulus, TXU

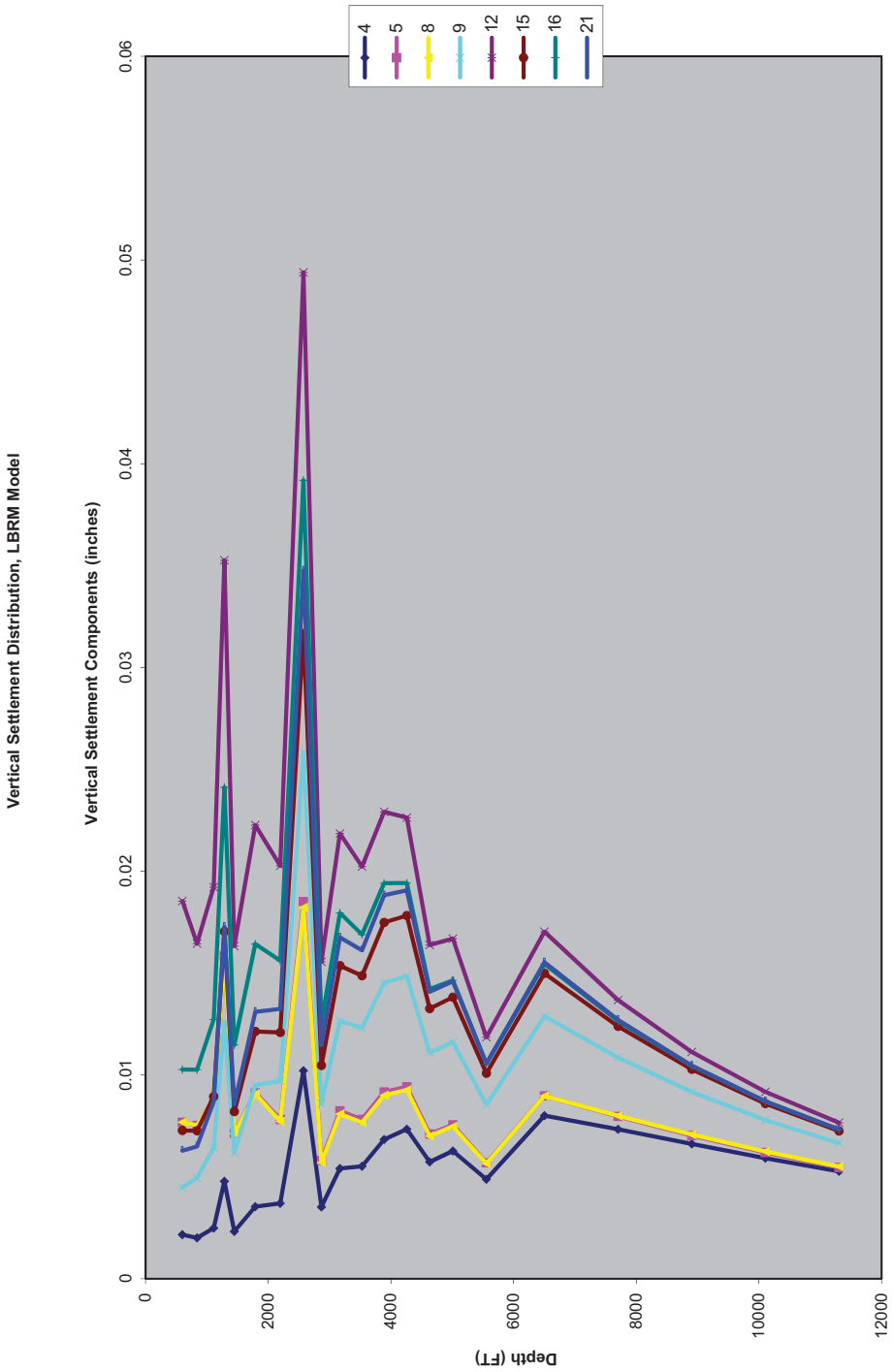
SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	0.0	940.6	**0.08**	**2**	267.0	940.6	**0.12**
3	267.0	780.6	**0.19**	**4**	0.0	780.6	**0.11**
5	133.5	860.6	**0.18**	**6**	600.1	940.6	**0.08**
7	333.1	780.6	**0.19**	**8**	466.6	860.6	**0.18**
9	112.7	680.5	**0.22**	**10**	286.2	680.5	**0.33**
11	459.7	680.5	**0.23**	**12**	459.7	513.2	**0.40**
13	459.7	345.9	**0.39**	**14**	286.2	345.9	**0.48**
15	112.7	345.9	**0.27**	**16**	112.7	513.2	**0.32**
17	286.2	513.2	**0.52**	**18**	525.7	520.0	**0.25**
19	525.7	345.9	**0.28**	**20**	492.7	433.0	**0.39**
21	149.2	295.2	**0.28**	**22**	547.7	295.2	**0.22**



Settlement Calculation, Layered Method, Lower Bound Modulus, TXU


Vertical Stress Increment Distribution, LBRM Model
Vertical Stress Increment (PSF)
0
2000
4000
6000
8000
10000
12000
14000
16000
Depth (FT)
0
100
200
300
400
500
600
700
800
900
1000
4
5
8
9
12
15
16
21
20% Overburden Line
10% Overburden Line


Vertical Settlement Distribution, LBRM Model
Vertical Settlement Components (inches)
0
0.01
0.02
0.03
0.04
0.05
0.06
0
2000
4000
6000
8000
10000
12000
Depth (FT)
4
5
8
9
12
15
16
21

MODULUS AVERAGING

LAYER ID	LAYER CENTER DEPTH FT	THICKNESS FT	MODULUS PSF	$\sum_{i=1}^{n}\left(E_i \Big/ \sum_{j=1}^{i} h_j\right)$	$\sum_{i=1}^{n}\left(1 \Big/ \sum_{j=1}^{i} h_j\right)$
1.00	3.00	6.00	155,547,652		
2.00	15.00	18.00	155,547,652		
3.00	28.00	8.00	44,262,695		
4.00	36.00	8.00	48,648,130		
5.00	50.00	20.00	405,550,066	20277503	0.050
6.00	70.00	20.00	405,550,066	10138752	0.025
7.00	92.50	25.00	405,550,066	6239232	0.015
8.00	107.00	4.00	59,687,742	865040	0.014
9.00	120.50	23.00	313,510,454	3407722	0.011
10.00	149.00	34.00	585,032,604	4643116	0.008
11.00	183.00	34.00	205,855,826	1286599	0.006
12.00	214.50	29.00	72,539,100	383805	0.005
13.00	239.00	20.00	110,220,264	527370	0.005
14.00	264.00	30.00	110,220,264	461173	0.004
15.00	294.00	30.00	110,220,264	409741	0.004
16.00	324.00	30.00	117,958,712	394511	0.003
17.00	355.00	32.00	117,958,712	356371	0.003
18.00	386.00	30.00	110,901,382	307206	0.003
19.00	417.50	33.00	110,901,382	281476	0.003
20.00	463.00	58.00	378,267,514	836875	0.002
21.00	542.00	100.00	378,267,514	685267	0.002
22.00	642.00	100.00	378,267,514	580165	0.002
23.00	742.00	100.00	378,267,514	503015	0.001
24.00	842.00	100.00	378,267,514	443976	0.001
25.00	942.00	100.00	378,267,514	397340	0.001

$$E_{dw} = \frac{\sum_{i=1}^{n}\left(E_i \Big/ \sum_{j=1}^{i} h_j\right)}{\sum_{i=1}^{n}\left(1 \Big/ \sum_{j=1}^{i} h_j\right)} = \begin{array}{ll} 2199 & \text{KSI} \\ 316701108 & \text{PSF} \end{array}$$

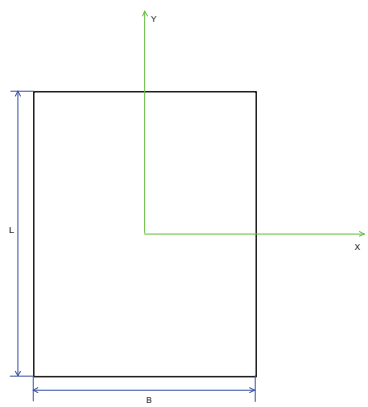
Weighted Modulus Calculation

NON-LAYERED METHOD--BERM MODEL

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS (NON-LAYERED)
BERM Model

Reference: Soil Mechanics Principles and Application, William Perloff and William Baron,1976,Page 199-201

METHODOLOGY:



The vertical Settlement of any point of the surface of an elastic half-space uniformly loaded over a rectangular area is expressed as:

$$\delta(x,y) = C(x,y)\frac{qB(1-\mu)}{E}$$

where d(x,y) is vertical settlement at point (x,y) by a rectangular foundation, q is the load intensity, B foundation width, L foundation length, p is poisson's ratio, E is modulus of deformation of the bearing rock. And C(x,y) is a geometric factor which accounts for shape of the rectangle shown in Figure 1 and the the position of the point for which the settlement is being calculated. C can be calculated based on following formulas:

$$C(x,y) = \frac{1}{2\pi}(C_1 + C_2 + C_3 + C_4)$$

$$C_1 = B_1 \ln\left(\frac{\sqrt{A_1^2 + B_1^2} + A_1}{\sqrt{A_2^2 + B_1^2} - A_2}\right) \qquad C_2 = B_2 \ln\left(\frac{\sqrt{A_1^2 + B_2^2} + A_1}{\sqrt{A_2^2 + B_2^2} - A_2}\right)$$

$$C_3 = A_1 \ln\left(\frac{\sqrt{A_1^2 + B_1^2} + B_1}{\sqrt{A_1^2 + B_2^2} - B_2}\right) \qquad C_4 = A_2 \ln\left(\frac{\sqrt{A_2^2 + B_1^2} + B_1}{\sqrt{A_2^2 + B_2^2} - B_2}\right)$$

$$A_1 = 1 - \frac{2x}{B} \qquad A_2 = 1 + \frac{2x}{B} \qquad B_1 = \frac{L}{B} - \frac{2y}{B} \qquad B_2 = \frac{L}{B} + \frac{2y}{B}$$

Appendix A

INPUT SUMMARY:

NUMBER OF LOADED AREAS= 7 POISSON'S RATIO= 0.30

NUMBER OF SETTLEMENT POINTS= 22 ELASTIC MODULUS= 316701 KSF

LOAD UNIT ID	LOAD INTENSITY PSF	LOAD UNIT CORNER COORDINATES (FT)							
		X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13100.0	112.7	679.5	459.7	679.5	459.7	344.9	112.7	344.9
2	4900.0	0.0	939.6	267.0	939.6	267.0	779.6	0.0	779.6
3	4900.0	333.1	939.6	600.1	939.6	600.1	779.6	333.1	779.6
4	4000.0	100.2	341.7	198.2	341.7	198.2	246.7	100.2	246.7
5	4000.0	498.7	341.7	596.7	341.7	596.7	246.7	498.7	246.7
6	13100.0	459.7	519.0	525.7	519.0	525.7	344.9	459.7	344.9
7	10000.0	198.2	342.7	463.7	342.7	463.7	0.0	198.2	0.0

SETTLEMENT POINT COORDINATES								
ID	X	Y	ID	X	Y	ID	X	Y
1	0.0	940.6	2	267.0	940.6	3	267.0	780.6
4	0.0	780.6	5	133.5	860.6	6	600.1	940.6
7	333.1	780.6	8	466.6	860.6	9	112.7	680.5
10	286.2	680.5	11	459.7	680.5	12	459.7	513.2
13	459.7	345.9	14	286.2	345.9	15	112.7	345.9
16	112.7	513.2	17	286.2	513.2	18	525.7	520.0
19	525.7	345.9	20	492.7	433.0	21	149.2	295.2
22	547.7	295.2						

Appendix A

OUTPUT SUMMARY:

CALCULATION BASED ON LOADED AREA 1						CALCULATION BASED ON LOADED AREA 2					
Settle ID	General Coordinates		Local Coordinates		Settlement Component	Settle ID	General Coordinates		Local Coordinates		Settlement Component
	X	Y	X'	Y'			X	Y	X'	Y'	
1	0.0	940.6	428.4	-286.2	0.002	1	0.0	940.6	81.0	-133.5	0.001
2	267.0	940.6	428.4	-19.2	0.003	2	267.0	940.6	81.0	133.5	0.001
3	267.0	780.6	268.4	-19.2	0.004	3	267.0	780.6	-79.0	133.5	0.001
4	0.0	780.6	268.4	-286.2	0.003	4	0.0	780.6	-79.0	-133.5	0.001
5	133.5	860.6	348.4	-152.7	0.003	5	133.5	860.6	1.0	0.0	0.002
6	600.1	940.6	428.4	313.9	0.002	6	600.1	940.6	81.0	466.6	0.000
7	333.1	780.6	268.4	46.9	0.004	7	333.1	780.6	-79.0	199.6	0.001
8	466.6	860.6	348.4	180.4	0.003	8	466.6	860.6	1.0	333.1	0.000
9	112.7	680.5	168.3	-173.5	0.006	9	112.7	680.5	-179.1	-20.8	0.001
10	286.2	680.5	168.3	0.0	0.007	10	286.2	680.5	-179.1	152.7	0.001
11	459.7	680.5	168.3	173.5	0.006	11	459.7	680.5	-179.1	326.2	0.000
12	459.7	513.2	1.0	173.5	0.008	12	459.7	513.2	-346.4	326.2	0.000
13	459.7	345.9	-166.3	173.5	0.006	13	459.7	345.9	-513.7	326.2	0.000
14	286.2	345.9	-166.3	0.0	0.008	14	286.2	345.9	-513.7	152.7	0.000
15	112.7	345.9	-166.3	-173.5	0.006	15	112.7	345.9	-513.7	-20.8	0.000
16	112.7	513.2	1.0	-173.5	0.008	16	112.7	513.2	-346.4	-20.8	0.000
17	286.2	513.2	1.0	0.0	0.011	17	286.2	513.2	-346.4	152.7	0.000
18	525.7	520.0	7.8	239.5	0.005	18	525.7	520.0	-339.6	392.2	0.000
19	525.7	345.9	-166.3	239.5	0.004	19	525.7	345.9	-513.7	392.2	0.000
20	492.7	433.0	-79.2	206.5	0.006	20	492.7	433.0	-426.6	359.2	0.000
21	149.2	295.2	-217.0	-137.0	0.005	21	149.2	295.2	-564.4	15.7	0.000
22	547.7	295.2	-217.0	261.5	0.003	22	547.7	295.2	-564.4	414.2	0.000

Appendix A

CALCULATION BASED ON LOADED AREA 3						CALCULATION BASED ON LOADED AREA 4					
Settle ID	General Coordinates		Local Coordinates		Settlement Component	Settle ID	General Coordinates		Local Coordinates		Settlement Component
	X	Y	X'	Y'			X	Y	X'	Y'	
1	0.0	940.6	81.0	-466.6	0.000	1	0.0	940.6	646.4	-149.2	0.000
2	267.0	940.6	81.0	-199.6	0.001	2	267.0	940.6	646.4	117.8	0.000
3	267.0	780.6	-79.0	-199.6	0.001	3	267.0	780.6	486.4	117.8	0.000
4	0.0	780.6	-79.0	-466.6	0.000	4	0.0	780.6	486.4	-149.2	0.000
5	133.5	860.6	1.0	-333.1	0.000	5	133.5	860.6	566.4	-15.7	0.000
6	600.1	940.6	81.0	133.5	0.001	6	600.1	940.6	646.4	450.9	0.000
7	333.1	780.6	-79.0	-133.5	0.001	7	333.1	780.6	486.4	183.9	0.000
8	466.6	860.6	1.0	0.0	0.002	8	466.6	860.6	566.4	317.4	0.000
9	112.7	680.5	-179.1	-353.9	0.000	9	112.7	680.5	386.3	-36.5	0.000
10	286.2	680.5	-179.1	-180.4	0.001	10	286.2	680.5	386.3	137.0	0.000
11	459.7	680.5	-179.1	-6.9	0.001	11	459.7	680.5	386.3	310.5	0.000
12	459.7	513.2	-346.4	-6.9	0.000	12	459.7	513.2	219.0	310.5	0.000
13	459.7	345.9	-513.7	-6.9	0.000	13	459.7	345.9	51.8	310.5	0.000
14	286.2	345.9	-513.7	-180.4	0.000	14	286.2	345.9	51.8	137.0	0.000
15	112.7	345.9	-513.7	-353.9	0.000	15	112.7	345.9	51.8	-36.5	0.000
16	112.7	513.2	-346.4	-353.9	0.000	16	112.7	513.2	219.0	-36.5	0.000
17	286.2	513.2	-346.4	-180.4	0.000	17	286.2	513.2	219.0	137.0	0.000
18	525.7	520.0	-339.6	59.1	0.000	18	525.7	520.0	225.8	376.5	0.000
19	525.7	345.9	-513.7	59.1	0.000	19	525.7	345.9	51.8	376.5	0.000
20	492.7	433.0	-426.6	26.1	0.000	20	492.7	433.0	138.8	343.5	0.000
21	149.2	295.2	-564.4	-317.4	0.000	21	149.2	295.2	1.0	0.0	0.001
22	547.7	295.2	-564.4	81.1	0.000	22	547.7	295.2	1.0	398.5	0.000

Appendix A

CALCULATION BASED ON LOADED AREA 5						CALCULATION BASED ON LOADED AREA 6					
Settle ID	General Coordinates		Local Coordinates		Settlement Component	Settle ID	General Coordinates		Local Coordinates		Settlement Component
	X	Y	X'	Y'			X	Y	X'	Y'	
1	0.0	940.6	646.4	-547.7	0.000	1	0.0	940.6	-492.7	508.6	0.000
2	267.0	940.6	646.4	-280.7	0.000	2	267.0	940.6	-225.7	508.6	0.000
3	267.0	780.6	486.4	-280.7	0.000	3	267.0	780.6	-225.7	348.6	0.000
4	0.0	780.6	486.4	-547.7	0.000	4	0.0	780.6	-492.7	348.6	0.000
5	133.5	860.6	566.4	-414.2	0.000	5	133.5	860.6	-359.2	428.6	0.000
6	600.1	940.6	646.4	52.4	0.000	6	600.1	940.6	107.4	508.6	0.000
7	333.1	780.6	486.4	-214.6	0.000	7	333.1	780.6	-159.6	348.6	0.000
8	466.6	860.6	566.4	-81.1	0.000	8	466.6	860.6	-26.1	428.6	0.000
9	112.7	680.5	386.3	-435.0	0.000	9	112.7	680.5	-380.0	248.5	0.000
10	286.2	680.5	386.3	-261.5	0.000	10	286.2	680.5	-206.5	248.5	0.000
11	459.7	680.5	386.3	-88.0	0.000	11	459.7	680.5	-33.0	248.5	0.000
12	459.7	513.2	219.0	-88.0	0.000	12	459.7	513.2	-33.0	81.2	0.002
13	459.7	345.9	51.8	-88.0	0.000	13	459.7	345.9	-33.0	-86.0	0.002
14	286.2	345.9	51.8	-261.5	0.000	14	286.2	345.9	-206.5	-86.0	0.000
15	112.7	345.9	51.8	-435.0	0.000	15	112.7	345.9	-380.0	-86.0	0.000
16	112.7	513.2	219.0	-435.0	0.000	16	112.7	513.2	-380.0	81.2	0.000
17	286.2	513.2	219.0	-261.5	0.000	17	286.2	513.2	-206.5	81.2	0.000
18	525.7	520.0	225.8	-22.0	0.000	18	525.7	520.0	33.0	88.0	0.002
19	525.7	345.9	51.8	-22.0	0.001	19	525.7	345.9	33.0	-86.0	0.002
20	492.7	433.0	138.8	-55.0	0.000	20	492.7	433.0	0.0	1.0	0.003
21	149.2	295.2	1.0	-398.5	0.000	21	149.2	295.2	-343.5	-136.8	0.000
22	547.7	295.2	1.0	0.0	0.001	22	547.7	295.2	55.0	-136.8	0.001

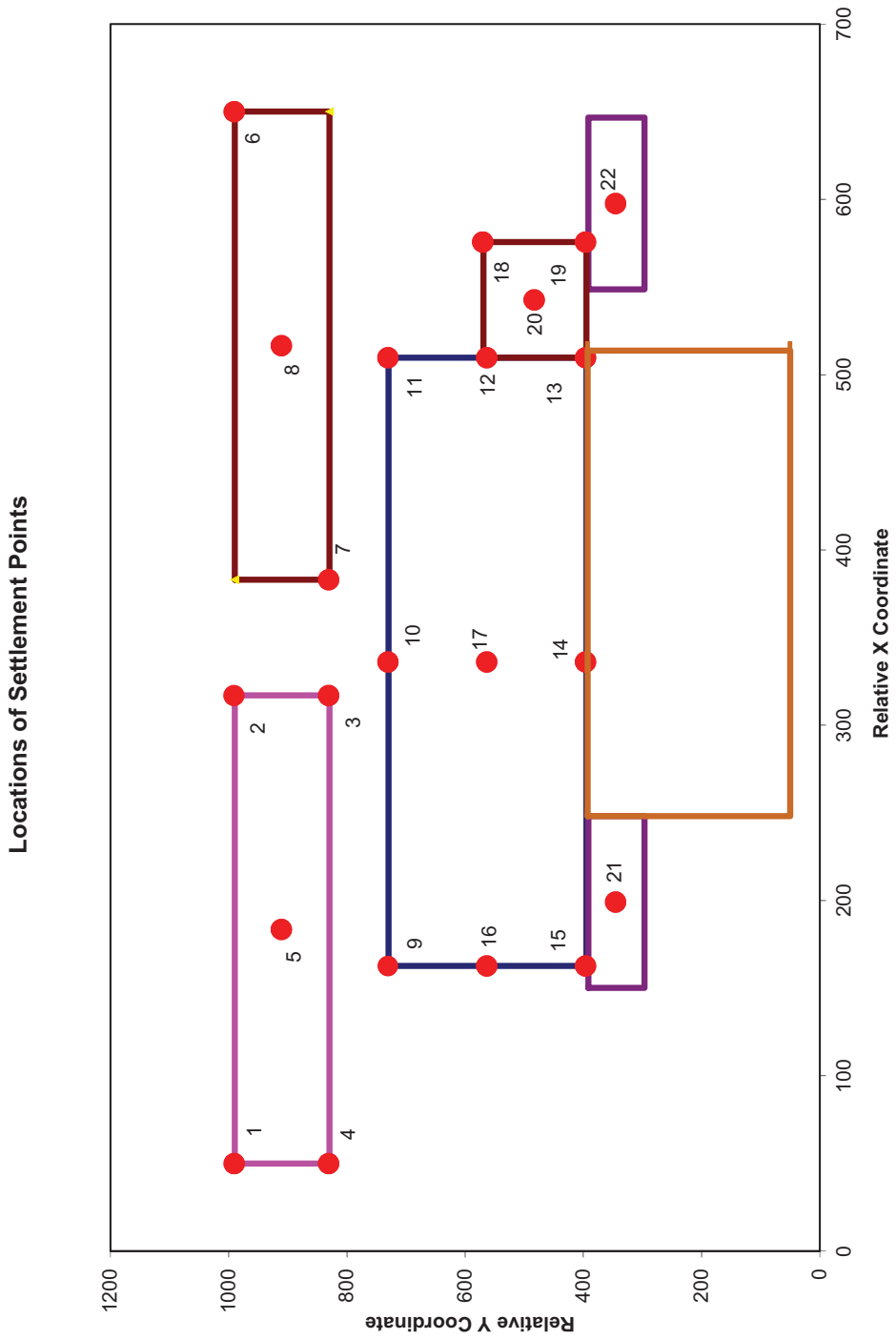
Appendix A

CALCULATION BASED ON LOADED AREA 7					
Settle ID	General Coordinates		Local Coordinates		Settlement Component
	X	Y	X'	Y'	
1	0.0	940.6	-330.9	769.3	0.001
2	267.0	940.6	-63.9	769.3	0.001
3	267.0	780.6	-63.9	609.3	0.001
4	0.0	780.6	-330.9	609.3	0.001
5	133.5	860.6	-197.4	689.3	0.001
6	600.1	940.6	269.2	769.3	0.001
7	333.1	780.6	2.2	609.3	0.001
8	466.6	860.6	135.7	689.3	0.001
9	112.7	680.5	-218.3	509.2	0.001
10	286.2	680.5	-44.8	509.2	0.001
11	459.7	680.5	128.8	509.2	0.001
12	459.7	513.2	128.8	341.9	0.002
13	459.7	345.9	128.8	174.6	0.004
14	286.2	345.9	-44.8	174.6	0.005
15	112.7	345.9	-218.3	174.6	0.002
16	112.7	513.2	-218.3	341.9	0.002
17	286.2	513.2	-44.8	341.9	0.002
18	525.7	520.0	194.8	348.7	0.002
19	525.7	345.9	194.8	174.6	0.003
20	492.7	433.0	161.8	261.6	0.002
21	149.2	295.2	-181.8	123.8	0.003
22	547.7	295.2	216.8	123.8	0.003

Appendix A

SUMMARY OF SETTLEMENT							
Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	0.00	940.59	0.06	2	267.00	940.59	0.07
3	267.00	780.59	0.09	4	0.00	780.59	0.07
5	133.50	860.59	0.08	6	600.08	940.59	0.06
7	333.08	780.59	0.09	8	466.58	860.59	0.08
9	112.67	680.50	0.10	10	286.17	680.50	0.13
11	459.67	680.50	0.10	12	459.67	513.21	0.15
13	459.67	345.92	0.14	14	286.17	345.92	0.16
15	112.67	345.92	0.11	16	112.67	513.21	0.13
17	286.17	513.21	0.17	18	525.67	520.00	0.11
19	525.67	345.92	0.11	20	492.67	432.96	0.14
21	149.17	295.17	0.12	22	547.67	295.17	0.10

Appendix A



Settlement Calculation, Non-Layered Method, Best Estimated Modulus, TXUT

MODULUS AVERAGING

LAYER ID	LAYER CENTER DEPTH FT	THICKNESS FT	MODULUS PSF	$\sum_{i=1}^{n}\left(E_i \Big/ \sum_{j=1}^{i} h_j\right)$	$\sum_{i=1}^{n}\left(1 \Big/ \sum_{j=1}^{i} h_j\right)$
1.00	3.00	6.00	91,508,416		
2.00	15.00	18.00	91,508,416		
3.00	28.00	8.00	11,650,143		
4.00	36.00	8.00	11,650,143		
5.00	50.00	20.00	139,212,424	6960621	0.050
6.00	70.00	20.00	139,212,424	3480311	0.025
7.00	92.50	25.00	139,212,424	2141730	0.015
8.00	107.00	4.00	11,650,143	168843	0.014
9.00	120.50	23.00	139,212,424	1513179	0.011
10.00	149.00	34.00	139,212,424	1104861	0.008
11.00	183.00	34.00	139,212,424	870078	0.006
12.00	214.50	29.00	44,754,165	236795	0.005
13.00	239.00	20.00	91,866,353	439552	0.005
14.00	264.00	30.00	91,866,353	384378	0.004
15.00	294.00	30.00	91,866,353	341511	0.004
16.00	324.00	30.00	75,174,273	251419	0.003
17.00	355.00	32.00	75,174,273	227113	0.003
18.00	386.00	30.00	90,209,128	249887	0.003
19.00	417.50	33.00	90,209,128	228957	0.003
20.00	463.00	58.00	200,298,272	443138	0.002
21.00	542.00	100.00	200,298,272	362859	0.002
22.00	642.00	100.00	200,298,272	307206	0.002
23.00	742.00	100.00	200,298,272	266354	0.001
24.00	842.00	100.00	200,298,272	235092	0.001
25.00	942.00	100.00	200,298,272	210397	0.001

$$E_{dw} = \frac{\sum_{i=1}^{n}\left(E_i \Big/ \sum_{j=1}^{i} h_j\right)}{\sum_{i=1}^{n}\left(1 \Big/ \sum_{j=1}^{i} h_j\right)} = \begin{array}{ll} 841 & \text{KSI} \\ 121071402 & \text{PSF} \end{array}$$

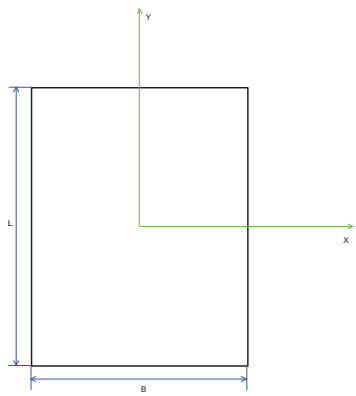
Weighted Modulus Calculation

NON-LAYERED METHOD--LBRM MODEL

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS (NON-LAYERED)
LBRM Model

Reference: Soil Mechanics Principles and Application, William Perloff and William Baron,1976,Page 199-201

METHODOLOGY:



The vertical Settlement of any point of the surface of an elastic half-space uniformly loaded over a rectangular area is expressed as:

$$\delta(x,y) = C(x,y)\frac{qB(1-\mu)}{E}$$

where d(x,y) is vertical settlement at point (x,y) by a rectangular foundation, q is the load intensity, B foundation width, L foundation length, p is poisson's ratio, E is modulus of deformation of the bearing rock. And C(x,y) is a geometric factor which accounts for shape of the rectangle shown in Figure 1 and the the position of the point for which the settlement is being calculated. C can be calculated based on following formulas:

$$C(x,y) = \frac{1}{2\pi}\left(C_1 + C_2 + C_3 + C_4\right)$$

$$C_1 = B_1 \ln\left(\frac{\sqrt{A_1^2 + B_1^2} + A_1}{\sqrt{A_2^2 + B_1^2} - A_2}\right) \qquad C_2 = B_2 \ln\left(\frac{\sqrt{A_1^2 + B_2^2} + A_1}{\sqrt{A_2^2 + B_2^2} - A_2}\right)$$

$$C_3 = A_1 \ln\left(\frac{\sqrt{A_1^2 + B_1^2} + B_1}{\sqrt{A_1^2 + B_2^2} - B_2}\right) \qquad C_4 = A_2 \ln\left(\frac{\sqrt{A_2^2 + B_1^2} + B_1}{\sqrt{A_2^2 + B_2^2} - B_2}\right)$$

$$A_1 = 1 - \frac{2x}{B} \qquad A_2 = 1 + \frac{2x}{B} \qquad B_1 = \frac{L}{B} - \frac{2y}{B} \qquad B_2 = \frac{L}{B} + \frac{2y}{B}$$

INPUT SUMMARY:

NUMBER OF LOADED AREAS= 7 POISSON'S RATIO= 0.30

NUMBER OF SETTLEMENT POINTS= 22 ELASTIC MODULUS= 121071 KSF

LOAD UNIT ID	LOAD INTENSITY PSF	LOAD UNIT CORNER COORDINATES (FT)							
		X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13100.0	112.7	679.5	459.7	679.5	459.7	344.9	112.7	344.9
2	4900.0	0.0	939.6	267.0	939.6	267.0	779.6	0.0	779.6
3	4900.0	333.1	939.6	600.1	939.6	600.1	779.6	333.1	779.6
4	4000.0	100.2	341.7	198.2	341.7	198.2	246.7	100.2	246.7
5	4000.0	498.7	341.7	596.7	341.7	596.7	246.7	498.7	246.7
6	13100.0	459.7	519.0	525.7	519.0	525.7	344.9	459.7	344.9
7	10000.0	198.2	342.7	463.7	342.7	463.7	0.0	198.2	0.0

SETTLEMENT POINT COORDINATES								
ID	X	Y	ID	X	Y	ID	X	Y
1	0.0	940.6	2	267.0	940.6	3	267.0	780.6
4	0.0	780.6	5	133.5	860.6	6	600.1	940.6
7	333.1	780.6	8	466.6	860.6	9	112.7	680.5
10	286.2	680.5	11	459.7	680.5	12	459.7	513.2
13	459.7	345.9	14	286.2	345.9	15	112.7	345.9
16	112.7	513.2	17	286.2	513.2	18	525.7	520.0
19	525.7	345.9	20	492.7	433.0	21	149.2	295.2
22	547.7	295.2						

OUTPUT SUMMARY:

CALCULATION BASED ON LOADED AREA 1						CALCULATION BASED ON LOADED AREA 2					
Settle ID	General Coordinates		Local Coordinates		Settlement Component	Settle ID	General Coordinates		Local Coordinates		Settlement Component
	X	Y	X'	Y'			X	Y	X'	Y'	
1	0.0	940.6	428.4	-286.2	0.006	1	0.0	940.6	81.0	-133.5	0.003
2	267.0	940.6	428.4	-19.2	0.007	2	267.0	940.6	81.0	133.5	0.003
3	267.0	780.6	268.4	-19.2	0.011	3	267.0	780.6	-79.0	133.5	0.003
4	0.0	780.6	268.4	-286.2	0.007	4	0.0	780.6	-79.0	-133.5	0.003
5	133.5	860.6	348.4	-152.7	0.008	5	133.5	860.6	1.0	0.0	0.006
6	600.1	940.6	428.4	313.9	0.005	6	600.1	940.6	81.0	466.6	0.001
7	333.1	780.6	268.4	46.9	0.011	7	333.1	780.6	-79.0	199.6	0.002
8	466.6	860.6	348.4	180.4	0.007	8	466.6	860.6	1.0	333.1	0.001
9	112.7	680.5	168.3	-173.5	0.015	9	112.7	680.5	-179.1	-20.8	0.002
10	286.2	680.5	168.3	0.0	0.020	10	286.2	680.5	-179.1	152.7	0.002
11	459.7	680.5	168.3	173.5	0.015	11	459.7	680.5	-179.1	326.2	0.001
12	459.7	513.2	1.0	173.5	0.020	12	459.7	513.2	-346.4	326.2	0.001
13	459.7	345.9	-166.3	173.5	0.015	13	459.7	345.9	-513.7	326.2	0.001
14	286.2	345.9	-166.3	0.0	0.020	14	286.2	345.9	-513.7	152.7	0.001
15	112.7	345.9	-166.3	-173.5	0.015	15	112.7	345.9	-513.7	-20.8	0.001
16	112.7	513.2	1.0	-173.5	0.020	16	112.7	513.2	-346.4	-20.8	0.001
17	286.2	513.2	1.0	0.0	0.029	17	286.2	513.2	-346.4	152.7	0.001
18	525.7	520.0	7.8	239.5	0.013	18	525.7	520.0	-339.6	392.2	0.001
19	525.7	345.9	-166.3	239.5	0.010	19	525.7	345.9	-513.7	392.2	0.001
20	492.7	433.0	-79.2	206.5	0.014	20	492.7	433.0	-426.6	359.2	0.001
21	149.2	295.2	-217.0	-137.0	0.012	21	149.2	295.2	-564.4	15.7	0.001
22	547.7	295.2	-217.0	261.5	0.009	22	547.7	295.2	-564.4	414.2	0.001

Appendix A

CALCULATION BASED ON LOADED AREA 3						CALCULATION BASED ON LOADED AREA 4					
Settle ID	General Coordinates		Local Coordinates		Settlement Component	Settle ID	General Coordinates		Local Coordinates		Settlement Component
	X	Y	X'	Y'			X	Y	X'	Y'	
1	0.0	940.6	81.0	-466.6	0.001	1	0.0	940.6	646.4	-149.2	0.000
2	267.0	940.6	81.0	-199.6	0.002	2	267.0	940.6	646.4	117.8	0.000
3	267.0	780.6	-79.0	-199.6	0.002	3	267.0	780.6	486.4	117.8	0.000
4	0.0	780.6	-79.0	-466.6	0.001	4	0.0	780.6	486.4	-149.2	0.000
5	133.5	860.6	1.0	-333.1	0.001	5	133.5	860.6	566.4	-15.7	0.000
6	600.1	940.6	81.0	133.5	0.003	6	600.1	940.6	646.4	450.9	0.000
7	333.1	780.6	-79.0	-133.5	0.003	7	333.1	780.6	486.4	183.9	0.000
8	466.6	860.6	1.0	0.0	0.006	8	466.6	860.6	566.4	317.4	0.000
9	112.7	680.5	-179.1	-353.9	0.001	9	112.7	680.5	386.3	-36.5	0.000
10	286.2	680.5	-179.1	-180.4	0.002	10	286.2	680.5	386.3	137.0	0.000
11	459.7	680.5	-179.1	-6.9	0.002	11	459.7	680.5	386.3	310.5	0.000
12	459.7	513.2	-346.4	-6.9	0.001	12	459.7	513.2	219.0	310.5	0.000
13	459.7	345.9	-513.7	-6.9	0.001	13	459.7	345.9	51.8	310.5	0.000
14	286.2	345.9	-513.7	-180.4	0.001	14	286.2	345.9	51.8	137.0	0.000
15	112.7	345.9	-513.7	-353.9	0.001	15	112.7	345.9	51.8	-36.5	0.001
16	112.7	513.2	-346.4	-353.9	0.001	16	112.7	513.2	219.0	-36.5	0.000
17	286.2	513.2	-346.4	-180.4	0.001	17	286.2	513.2	219.0	137.0	0.000
18	525.7	520.0	-339.6	59.1	0.001	18	525.7	520.0	225.8	376.5	0.000
19	525.7	345.9	-513.7	59.1	0.001	19	525.7	345.9	51.8	376.5	0.000
20	492.7	433.0	-426.6	26.1	0.001	20	492.7	433.0	138.8	343.5	0.000
21	149.2	295.2	-564.4	-317.4	0.001	21	149.2	295.2	1.0	0.0	0.003
22	547.7	295.2	-564.4	81.1	0.001	22	547.7	295.2	1.0	398.5	0.000

Appendix A

CALCULATION BASED ON LOADED AREA 5						CALCULATION BASED ON LOADED AREA 6					
Settle ID	General Coordinates		Local Coordinates		Settlement Component	Settle ID	General Coordinates		Local Coordinates		Settlement Component
	X	Y	X'	Y'			X	Y	X'	Y'	
1	0.0	940.6	646.4	-547.7	0.000	1	0.0	940.6	-492.7	508.6	0.000
2	267.0	940.6	646.4	-280.7	0.000	2	267.0	940.6	-225.7	508.6	0.001
3	267.0	780.6	486.4	-280.7	0.000	3	267.0	780.6	-225.7	348.6	0.001
4	0.0	780.6	486.4	-547.7	0.000	4	0.0	780.6	-492.7	348.6	0.000
5	133.5	860.6	566.4	-414.2	0.000	5	133.5	860.6	-359.2	428.6	0.000
6	600.1	940.6	646.4	52.4	0.000	6	600.1	940.6	107.4	508.6	0.001
7	333.1	780.6	486.4	-214.6	0.000	7	333.1	780.6	-159.6	348.6	0.001
8	466.6	860.6	566.4	-81.1	0.000	8	466.6	860.6	-26.1	428.6	0.001
9	112.7	680.5	386.3	-435.0	0.000	9	112.7	680.5	-380.0	248.5	0.001
10	286.2	680.5	386.3	-261.5	0.000	10	286.2	680.5	-206.5	248.5	0.001
11	459.7	680.5	386.3	-88.0	0.000	11	459.7	680.5	-33.0	248.5	0.001
12	459.7	513.2	219.0	-88.0	0.000	12	459.7	513.2	-33.0	81.2	0.005
13	459.7	345.9	51.8	-88.0	0.001	13	459.7	345.9	-33.0	-86.0	0.004
14	286.2	345.9	51.8	-261.5	0.000	14	286.2	345.9	-206.5	-86.0	0.001
15	112.7	345.9	51.8	-435.0	0.000	15	112.7	345.9	-380.0	-86.0	0.001
16	112.7	513.2	219.0	-435.0	0.000	16	112.7	513.2	-380.0	81.2	0.001
17	286.2	513.2	219.0	-261.5	0.000	17	286.2	513.2	-206.5	81.2	0.001
18	525.7	520.0	225.8	-22.0	0.000	18	525.7	520.0	33.0	88.0	0.004
19	525.7	345.9	51.8	-22.0	0.001	19	525.7	345.9	33.0	-86.0	0.004
20	492.7	433.0	138.8	-55.0	0.000	20	492.7	433.0	0.0	1.0	0.009
21	149.2	295.2	1.0	-398.5	0.000	21	149.2	295.2	-343.5	-136.8	0.001
22	547.7	295.2	1.0	0.0	0.003	22	547.7	295.2	55.0	-136.8	0.002

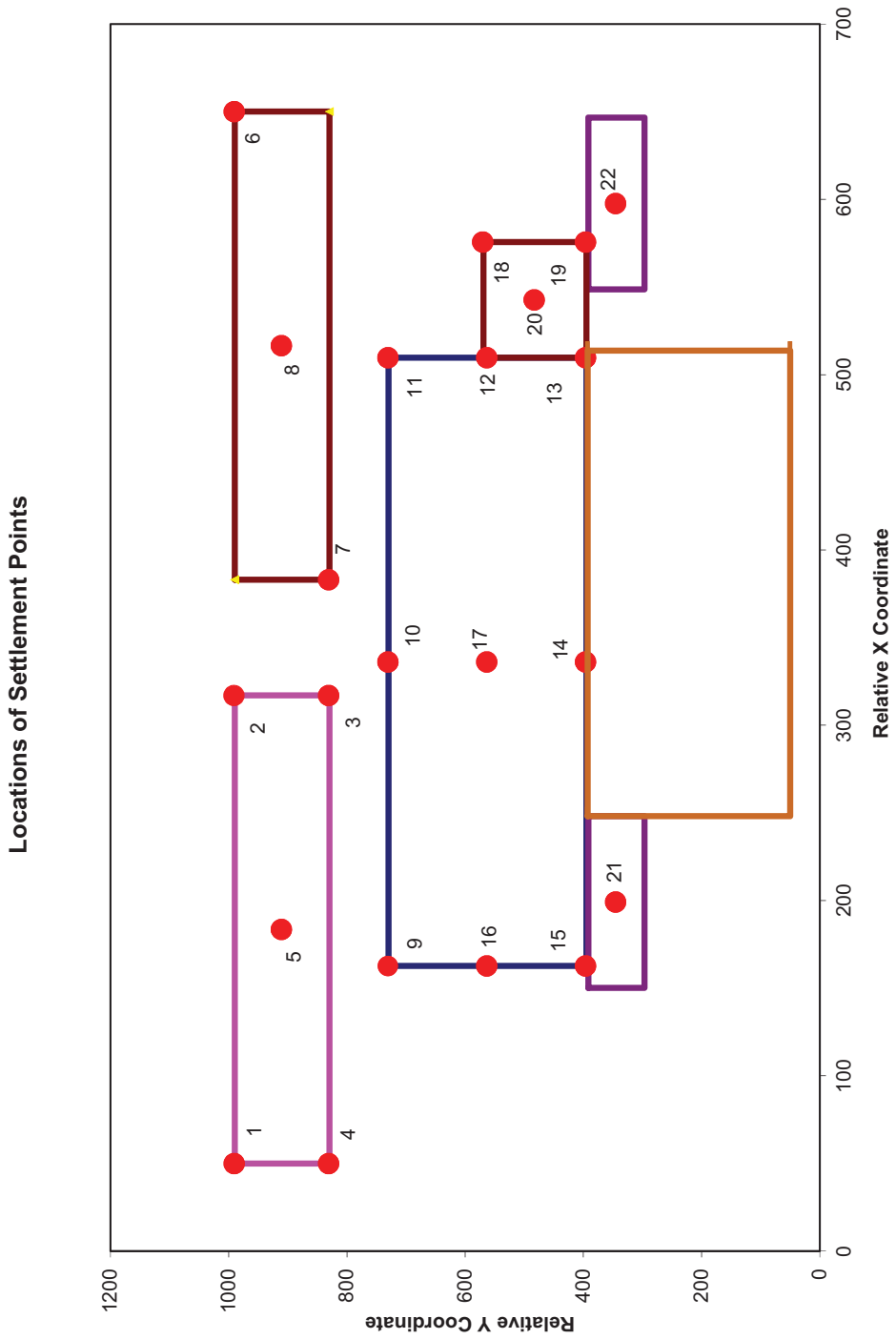
Appendix A

CALCULATION BASED ON LOADED AREA 7					
Settle ID	General Coordinates		Local Coordinates		Settlement Component
	X	Y	X'	Y'	
1	0.0	940.6	-330.9	769.3	0.002
2	267.0	940.6	-63.9	769.3	0.002
3	267.0	780.6	-63.9	609.3	0.003
4	0.0	780.6	-330.9	609.3	0.002
5	133.5	860.6	-197.4	689.3	0.002
6	600.1	940.6	269.2	769.3	0.002
7	333.1	780.6	2.2	609.3	0.003
8	466.6	860.6	135.7	689.3	0.002
9	112.7	680.5	-218.3	509.2	0.003
10	286.2	680.5	-44.8	509.2	0.003
11	459.7	680.5	128.8	509.2	0.003
12	459.7	513.2	128.8	341.9	0.005
13	459.7	345.9	128.8	174.6	0.010
14	286.2	345.9	-44.8	174.6	0.012
15	112.7	345.9	-218.3	174.6	0.006
16	112.7	513.2	-218.3	341.9	0.004
17	286.2	513.2	-44.8	341.9	0.005
18	525.7	520.0	194.8	348.7	0.004
19	525.7	345.9	194.8	174.6	0.007
20	492.7	433.0	161.8	261.6	0.006
21	149.2	295.2	-181.8	123.8	0.008
22	547.7	295.2	216.8	123.8	0.007

Appendix A

SUMMARY OF SETTLEMENT							
Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	0.00	940.59	0.15	2	267.00	940.59	0.18
3	267.00	780.59	0.24	4	0.00	780.59	0.18
5	133.50	860.59	0.22	6	600.08	940.59	0.15
7	333.08	780.59	0.24	8	466.58	860.59	0.22
9	112.67	680.50	0.26	10	286.17	680.50	0.33
11	459.67	680.50	0.27	12	459.67	513.21	0.39
13	459.67	345.92	0.38	14	286.17	345.92	0.43
15	112.67	345.92	0.30	16	112.67	513.21	0.33
17	286.17	513.21	0.45	18	525.67	520.00	0.28
19	525.67	345.92	0.30	20	492.67	432.96	0.37
21	149.17	295.17	0.30	22	547.67	295.17	0.26

Appendix A



Settlement Calculation, Non-Layered Method, Lower Bound Modulus, TXU

SETTLEMENT ANALYSIS OF LAYERED SITE-BERM Model, Mathcad Sheet for Cross Check against Excel Sheet

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment: The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\Delta\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, *m=L/Z, N=B/Z*, and *B, L* and *Z* are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than π/2 when $m^2+n^2+1>m^2n^2$, otherwise between π/2 and π.

Settlement Calculation:The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^{\,2}}{E_i}$$

where H, E and μ are layer thickness, modulus and poisson ratio, respectively.

Total Settlement: $S = \sum_{1}^{n} S_i$

where n is number of the total layeres influeenced by foundation pressures

DATA INPUT

Number of Loaded Area: NLA := 7 (Maximum 20)

Number of Stress Points in Z Direction: NSPZ := 25 (Maximum 40)

Number of Settlement Points in Plane: NSPP := 22 (Maximum 40)

Stress Calculation Method: ISCC := 1 (1. Boussinesq)

Loaded Area:	1	2	3	4	5	6	7
Loaded Intensity (PSF) of Each Loaded Area:	13100	4900	4900	4100	4100	13100	10000
Embedment Depth (FT) of Each Loaded Area:	40	40	40	40	40	40	40

Coordinates (FT) of Corners of Each Loaded Rectangle:

	X1	Y1	X2	Y2	X3	Y3	X4	Y4
Loaded Area 1	112.6667	679.5033	459.6667	679.5033	459.6667	344.92	112.6667	344.92
Loaded Area 2	0	939.5867	267	939.5867	267	779.5867	0	779.5867
Loaded Area 3	333.0833	939.5867	600.0833	939.5867	600.0833	779.5867	333.0833	779.5867
Loaded Area 4	100.1667	341.67	198.1667	341.67	198.1667	246.67	100.1667	246.67
Loaded Area 5	498.6667	341.67	596.6667	341.67	596.6667	246.67	498.6667	246.67
Loaded Area 6	459.6667	519.0033	525.6667	519.0033	525.6667	344.92	459.6667	344.92
Loaded Area 7	198.1667	342.67	463.6667	342.67	463.6667	0	198.1667	0

Layer	Depth to Layer Center (FT)	Modulus (PSF)	Poisson Ratio
1	3.00	155,547,652	0.3
2	15.00	155,547,652	0.3
3	28.00	44,262,695	0.3
4	36.00	48,648,130	0.3
5	50.00	405,550,066	0.3
6	70.00	405,550,066	0.3
7	92.50	405,550,066	0.3
8	107.00	59,687,742	0.3
9	120.50	313,510,454	0.3
10	149.00	585,032,604	0.3
11	183.00	205,855,826	0.3
12	214.50	72,539,100	0.3
13	239.00	110,220,264	0.3
14	264.00	110,220,264	0.3
15	294.00	110,220,264	0.3
16	324.00	117,958,712	0.3
17	355.00	117,958,712	0.3
18	386.00	110,901,382	0.3
19	417.50	110,901,382	0.3
20	463.00	378,267,514	0.3
21	542.00	378,267,514	0.3
22	642.00	378,267,514	0.3
23	742.00	378,267,514	0.3
24	842.00	378,267,514	0.3

Coords of Settlement Points (FT)

X	Y
0	940.5867
267	940.5867
267	780.5867
0	780.5867
133.5	860.5867
600.0833	940.5867
333.0833	780.5867
466.5833	860.5867
112.6667	680.5033
286.1667	680.5033
459.6667	680.5033
459.6667	513.2117
459.6667	345.92
286.1667	345.92
112.6667	345.92
112.6667	513.2117
286.1667	513.2117
525.6667	520.0033
525.6667	345.92
492.6667	432.9617
149.1667	295.17

RESULTS:

Stress Increment Matrix (PSF): The column index is layer Identification number, and the row index is settlement point number. The total stress increment contributed by all loaded areas at each layer center of each settlement point.

Stressinc =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	0	0	0	0	1070	1171	1183	1178	1169	1139	1097	1062	1041	1026	1014	1008	1006	1006	1006	1004	991	954	900	837	770
2	0	0	0	0	1072	1208	1321	1397	1461	1566	1640	1676	1689	1695	1692	1681	1663	1639	1609	1558	1456	1317	1179	1051	935
3	0	0	0	0	1384	1370	1630	1877	2126	2619	3046	3269	3348	3365	3325	3241	3127	2997	2857	2653	2317	1948	1644	1397	1196
4	0	0	0	0	1380	1280	1269	1275	1288	1327	1387	1443	1483	1517	1549	1569	1580	1580	1571	1544	1469	1346	1214	1085	967
5	0	0	0	0	4896	4802	4500	4230	3961	3425	2931	2617	2444	2312	2195	2104	2026	1957	1892	1801	1648	1462	1290	1137	1002
6	0	0	0	0	1070	1170	1183	1177	1167	1135	1091	1053	1031	1014	1001	995	994	995	997	999	991	960	909	846	780
7	0	0	0	0	1384	1369	1626	1869	2114	2598	3016	3236	3315	3334	3299	3220	3110	2984	2848	2649	2317	1950	1647	1400	1198
8	0	0	0	0	4896	4801	4496	4222	3949	3403	2897	2575	2399	2267	2152	2065	1993	1931	1871	1789	1646	1468	1299	1146	1011
9	0	0	0	0	2862	3156	3282	3360	3432	3559	3642	3648	3614	3552	3452	3333	3197	3056	2910	2702	2364	1991	1682	1429	1222
10	0	0	0	0	5722	6274	6393	6418	6418	6345	6144	5877	5635	5374	5053	4735	4419	4119	3834	3457	2900	2345	1922	1595	1339
11	0	0	0	0	2862	3160	3300	3394	3484	3659	3799	3849	3839	3793	3702	3583	3441	3289	3129	2900	2523	2108	1767	1491	1268
12	0	0	0	0	1818	0484	9802	9406	9051	8349	7600	6981	6543	6130	5676	5261	4870	4513	4181	3751	3126	2510	2042	1684	1406
13	0	0	0	0	9558	9318	9041	8810	8571	8043	7429	6895	6503	6125	5697	5297	4912	4555	4220	3783	3143	2515	2040	1679	1400
14	0	0	0	0	0441	1102	1125	1012	0849	0375	9667	8950	8386	7822	7176	6573	6001	5482	5005	4402	3557	2770	2204	1788	1475
15	0	0	0	0	4659	4657	4583	4569	4567	4568	4546	4486	4412	4316	4176	4017	3839	3653	3463	3191	2751	2274	1887	1578	1331
16	0	0	0	0	6550	6538	6491	6435	6364	6162	5855	5540	5289	5035	4740	4457	4179	3918	3668	3337	2836	2321	1916	1598	1345
17	0	0	0	0	3098	3060	2903	2717	2482	1818	0829	9848	9098	8373	7573	6856	6199	5619	5102	4462	3588	2789	2218	1800	1485
18	0	0	0	0	2865	3234	3546	3752	3925	4189	4330	4334	4282	4193	4057	3901	3726	3547	3364	3105	2688	2233	1862	1562	1322
19	0	0	0	0	4732	4952	4937	4931	4923	4880	4781	4651	4531	4395	4219	4034	3837	3639	3440	3163	2722	2249	1867	1563	1320
20	0	0	0	0	3027	2022	0465	9612	8947	7872	6979	6367	5973	5618	5236	4887	4556	4249	3960	3579	3012	2439	1996	1653	1384
21	0	0	0	0	4107	4229	4497	4660	4782	4940	4984	4925	4833	4707	4527	4325	4106	3883	3657	3344	2850	2331	1921	1598	1344
22	0	0	0	0	4083	3803	3376	3224	3174	3231	3372	3465	3495	3492	3448	3371	3267	3146	3013	2813	2470	2079	1750	1480	1260

Settlements Matrix (Inches): The row index of the matrix is settlement point number, and the column index is layer identification number. The Settlement in this matrix is total settlement contributed by each loaded area at each layer of each settlement point.

SettleComp =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	0	0	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.005	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.003	0.003	0.003	0.002	0.002
2	0	0	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.007	0.003	0.005	0.005	0.005	0.005	0.005	0.005	0.003	0.004	0.004	0.003	0.003	0.003
3	0	0	0	0	0.001	0.001	0.001	0.001	0.002	0.002	0.005	0.014	0.007	0.01	0.01	0.009	0.009	0.009	0.009	0.004	0.007	0.006	0.005	0.004	0.003
4	0	0	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.006	0.003	0.005	0.005	0.004	0.005	0.005	0.005	0.003	0.004	0.004	0.004	0.003	0.003
5	0	0	0	0	0.003	0.003	0.003	0.003	0.003	0.002	0.005	0.011	0.005	0.007	0.007	0.006	0.006	0.006	0.006	0.003	0.005	0.004	0.004	0.003	0.003
6	0	0	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.005	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.003	0.003	0.003	0.002	0.002
7	0	0	0	0	0.001	0.001	0.001	0.001	0.002	0.002	0.005	0.014	0.007	0.01	0.01	0.009	0.009	0.009	0.009	0.004	0.007	0.006	0.005	0.004	0.003
8	0	0	0	0	0.003	0.003	0.003	0.003	0.003	0.002	0.005	0.011	0.005	0.007	0.006	0.006	0.006	0.006	0.006	0.003	0.005	0.004	0.004	0.003	0.003
9	0	0	0	0	0.002	0.002	0.002	0.002	0.003	0.002	0.007	0.016	0.007	0.011	0.01	0.009	0.009	0.009	0.009	0.005	0.007	0.006	0.005	0.004	0.004
10	0	0	0	0	0.003	0.003	0.004	0.005	0.005	0.004	0.011	0.026	0.011	0.016	0.015	0.013	0.013	0.012	0.012	0.006	0.008	0.007	0.006	0.005	0.004
11	0	0	0	0	0.002	0.002	0.002	0.002	0.003	0.002	0.007	0.017	0.008	0.011	0.011	0.01	0.01	0.01	0.01	0.005	0.007	0.006	0.005	0.004	0.004
12	0	0	0	0	0.006	0.006	0.007	0.007	0.007	0.005	0.014	0.03	0.013	0.018	0.017	0.015	0.014	0.013	0.014	0.006	0.009	0.007	0.006	0.005	0.004
13	0	0	0	0	0.005	0.005	0.006	0.006	0.007	0.005	0.013	0.03	0.013	0.018	0.017	0.015	0.015	0.013	0.014	0.006	0.009	0.007	0.006	0.005	0.004
14	0	0	0	0	0.006	0.006	0.007	0.008	0.009	0.007	0.017	0.039	0.017	0.023	0.021	0.018	0.018	0.016	0.016	0.007	0.01	0.008	0.006	0.005	0.004
15	0	0	0	0	0.003	0.003	0.003	0.003	0.004	0.003	0.008	0.02	0.009	0.013	0.012	0.011	0.011	0.011	0.011	0.005	0.008	0.007	0.005	0.005	0.004
16	0	0	0	0	0.004	0.004	0.004	0.005	0.005	0.004	0.011	0.024	0.01	0.015	0.014	0.012	0.012	0.012	0.012	0.006	0.008	0.007	0.006	0.005	0.004
17	0	0	0	0	0.007	0.007	0.009	0.009	0.01	0.008	0.02	0.043	0.018	0.025	0.023	0.019	0.018	0.017	0.017	0.007	0.01	0.008	0.006	0.005	0.004
18	0	0	0	0	0.002	0.002	0.002	0.003	0.003	0.003	0.008	0.019	0.008	0.012	0.012	0.011	0.011	0.01	0.011	0.005	0.008	0.006	0.005	0.005	0.004
19	0	0	0	0	0.003	0.003	0.003	0.004	0.004	0.003	0.009	0.02	0.009	0.013	0.013	0.011	0.011	0.011	0.011	0.005	0.008	0.006	0.005	0.005	0.004
20	0	0	0	0	0.007	0.006	0.007	0.007	0.007	0.005	0.013	0.028	0.012	0.017	0.016	0.014	0.013	0.013	0.013	0.006	0.009	0.007	0.006	0.005	0.004
21	0	0	0	0	0.002	0.002	0.003	0.003	0.004	0.003	0.009	0.022	0.01	0.014	0.013	0.012	0.012	0.011	0.012	0.006	0.008	0.007	0.006	0.005	0.004
22	0	0	0	0	0.002	0.002	0.002	0.002	0.003	0.002	0.006	0.015	0.007	0.01	0.01	0.009	0.01	0.009	0.01	0.005	0.007	0.006	0.005	0.004	0.004

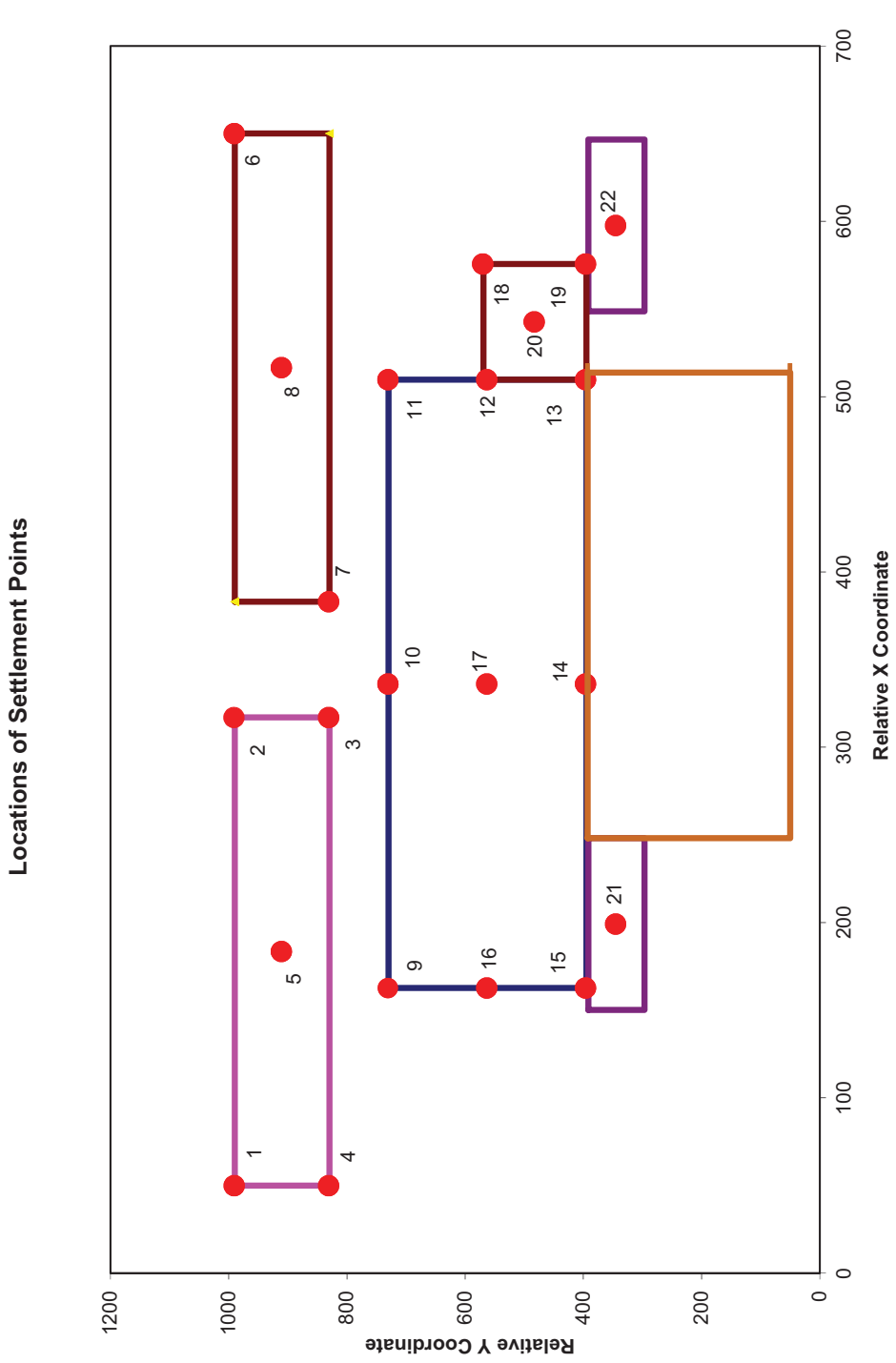
$Settle := TotalSettle(NSPP, NSPZ, SettleComp)$

Total Settlement Matrix (Inches)

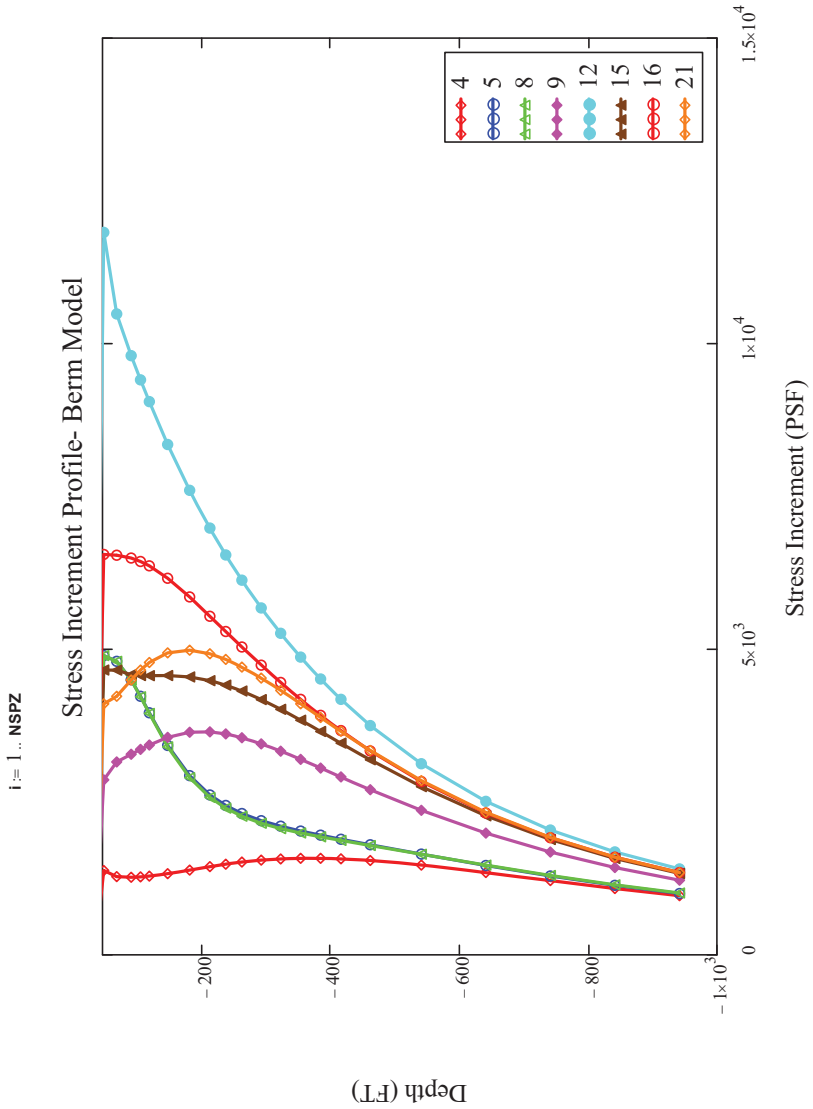
(Column index is the settlement point number)

$Settle^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.05	0.07	0.12	0.06	0.1	0.05	0.12	0.1	0.13	0.19	0.14	0.22	0.22	0.27	0.16	0.18	0.29	0.15	0.16	0.21	0.17	0.13



Settlement Calculation, Layered Method, Best Estimated Modulus, TXU


i := 1 .. NSPZ
Stress Increment Profile- Berm Model
Depth (FT)
Stress Increment (PSF)
-200
-400
-600
-800
-1×10^3
0
5×10^3
1×10^4
1.5×10^4
4
5
8
9
12
15
16
21

SETTLEMENT ANALYSIS OF LAYERED SITE-LRBM Model, Mathcad Sheet for Cross Check against Excel Sheet

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment: The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\Delta\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, *m=L/Z, N=B/Z*, and *B, L* and *Z* are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than π/2 when $m^2+n^2+1>m^2n^2$, otherwise between π/2 and π.

Settlement Calculation:The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and μ are layer thickness, modulus and poisson ratio, respectively.

Total Settlement: $S = \sum_1^n S_i$

where n is number of the total layeres influeenced by foundation pressures

DATA INPUT

Number of Loaded Area:	NLA := 7	(Maximum 20)
Number of Stress Points in Z Direction:	NSPZ := 25	(Maximum 40)
Number of Settlement Points in Plane:	NSPP := 22	(Maximum 40)
Stress Calculation Method:	ISCC := 1	(1. Boussinesq)

Loaded Area:	1	2	3	4	5	6	7
Loaded Intensity (PSF) of Each Loaded Area:	13100	4900	4900	4100	4100	13100	10000
Embedment Depth (FT) of Each Loaded Area:	40	40	40	40	40	40	40

Coordinates (FT) of Corners of Each Loaded Rectangle:

	X1	Y1	X2	Y2	X3	Y3	X4	Y4
Loaded Area 1	112.6667	679.5033	459.6667	679.5033	459.6667	344.92	112.6667	344.92
Loaded Area 2	0	939.5867	267	939.5867	267	779.5867	0	779.5867
Loaded Area 3	333.0833	939.5867	600.0833	939.5867	600.0833	779.5867	333.0833	779.5867
Loaded Area 4	100.1667	341.67	198.1667	341.67	198.1667	246.67	100.1667	246.67
Loaded Area 5	498.6667	341.67	596.6667	341.67	596.6667	246.67	498.6667	246.67
Loaded Area 6	459.6667	519.0033	525.6667	519.0033	525.6667	344.92	459.6667	344.92
Loaded Area 7	198.1667	342.67	463.6667	342.67	463.6667	0	198.1667	0

Layer	Depth to Layer Center (FT)	Modulus (PSF)	Poisson Ratio
1	3.00	91,508,416	0.3
2	15.00	91,508,416	0.3
3	28.00	11,650,143	0.3
4	36.00	11,650,143	0.3
5	50.00	139,212,424	0.3
6	70.00	139,212,424	0.3
7	92.50	139,212,424	0.3
8	107.00	11,650,143	0.3
9	120.50	139,212,424	0.3
10	149.00	139,212,424	0.3
11	183.00	139,212,424	0.3
12	214.50	44,754,165	0.3
13	239.00	91,866,353	0.3
14	264.00	91,866,353	0.3
15	294.00	91,866,353	0.3
16	324.00	75,174,273	0.3
17	355.00	75,174,273	0.3
18	386.00	90,209,128	0.3
19	417.50	90,209,128	0.3
20	463.00	200,298,272	0.3
21	542.00	200,298,272	0.3
22	642.00	200,298,272	0.3
23	742.00	200,298,272	0.3
24	842.00	200,298,272	0.3

Coords of Settlement Points (FT)

X	Y
0	940.5867
267	940.5867
267	780.5867
0	780.5867
133.5	860.5867
600.0833	940.5867
333.0833	780.5867
466.5833	860.5867
112.6667	680.5033
286.1667	680.5033
459.6667	680.5033
459.6667	513.2117
459.6667	345.92
286.1667	345.92
112.6667	345.92
112.6667	513.2117
286.1667	513.2117
525.6667	520.0033
525.6667	345.92
492.6667	432.9617
149.1667	295.17

RESULTS:

Stress Increment Matrix (PSF): The column index is layer Identification number, and the row index is settlement point number. The total stress increment contributed by all loaded areas at each layer center of each settlement point.

Stressinc =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	0	0	0	0	1070	1171	1183	1178	1169	1139	1097	1062	1041	1026	1014	1008	1006	1006	1006	1004	991	954	900	837	770
2	0	0	0	0	1072	1208	1321	1397	1461	1566	1640	1676	1689	1695	1692	1681	1663	1639	1609	1558	1456	1317	1179	1051	935
3	0	0	0	0	1384	1370	1630	1877	2126	2619	3046	3269	3348	3365	3325	3241	3127	2997	2857	2653	2317	1948	1644	1397	1196
4	0	0	0	0	1380	1280	1269	1275	1288	1327	1387	1443	1483	1517	1549	1569	1580	1580	1571	1544	1469	1346	1214	1085	967
5	0	0	0	0	4896	4802	4500	4230	3961	3425	2931	2617	2444	2312	2195	2104	2026	1957	1892	1801	1648	1462	1290	1137	1002
6	0	0	0	0	1070	1170	1183	1177	1167	1135	1091	1053	1031	1014	1001	995	994	995	997	999	991	960	909	846	780
7	0	0	0	0	1384	1369	1626	1869	2114	2598	3016	3236	3315	3334	3299	3220	3110	2984	2848	2649	2317	1950	1647	1400	1198
8	0	0	0	0	4896	4801	4496	4222	3949	3403	2897	2575	2399	2267	2152	2065	1993	1931	1871	1789	1646	1468	1299	1146	1011
9	0	0	0	0	2862	3156	3282	3360	3432	3559	3642	3648	3614	3552	3452	3333	3197	3056	2910	2702	2364	1991	1682	1429	1222
10	0	0	0	0	5722	6274	6393	6418	6418	6345	6144	5877	5635	5374	5053	4735	4419	4119	3834	3457	2900	2345	1922	1595	1339
11	0	0	0	0	2862	3160	3300	3394	3484	3659	3799	3849	3839	3793	3702	3583	3441	3289	3129	2900	2523	2108	1767	1491	1268
12	0	0	0	0	1818	0484	9802	9406	9051	8349	7600	6981	6543	6130	5676	5261	4870	4513	4181	3751	3126	2510	2042	1684	1406
13	0	0	0	0	9558	9318	9041	8810	8571	8043	7429	6895	6503	6125	5697	5297	4912	4555	4220	3783	3143	2515	2040	1679	1400
14	0	0	0	0	0441	1102	1125	1012	0849	0375	9667	8950	8386	7822	7176	6573	6001	5482	5005	4402	3557	2770	2204	1788	1475
15	0	0	0	0	4659	4657	4583	4569	4567	4568	4546	4486	4412	4316	4176	4017	3839	3653	3463	3191	2751	2274	1887	1578	1331
16	0	0	0	0	6550	6538	6491	6435	6364	6162	5855	5540	5289	5035	4740	4457	4179	3918	3668	3337	2836	2321	1916	1598	1345
17	0	0	0	0	3098	3060	2903	2717	2482	1818	0829	9848	9098	8373	7573	6856	6199	5619	5102	4462	3588	2789	2218	1800	1485
18	0	0	0	0	2865	3234	3546	3752	3925	4189	4330	4334	4282	4193	4057	3901	3726	3547	3364	3105	2688	2233	1862	1562	1322
19	0	0	0	0	4732	4952	4937	4931	4923	4880	4781	4651	4531	4395	4219	4034	3837	3639	3440	3163	2722	2249	1867	1563	1320
20	0	0	0	0	3027	2022	0465	9612	8947	7872	6979	6367	5973	5618	5236	4887	4556	4249	3960	3579	3012	2439	1996	1653	1384
21	0	0	0	0	4107	4229	4497	4660	4782	4940	4984	4925	4833	4707	4527	4325	4106	3883	3657	3344	2850	2331	1921	1598	1344
22	0	0	0	0	4083	3803	3376	3224	3174	3231	3372	3465	3495	3492	3448	3371	3267	3146	3013	2813	2470	2079	1750	1480	1260

Settlements Matrix (Inches): The row index of the matrix is settlement point number, and the column index is layer identification number. The Settlement in this matrix is total settlement contributed by each loaded area at each layer of each settlement point.

SettleComp =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	0	0	0	0	0.002	0.002	0.002	0.004	0.002	0.003	0.003	0.008	0.002	0.004	0.004	0.004	0.005	0.004	0.004	0.003	0.005	0.005	0.005	0.005	0.004
2	0	0	0	0	0.002	0.002	0.003	0.005	0.003	0.004	0.004	0.012	0.004	0.006	0.006	0.007	0.008	0.006	0.006	0.005	0.008	0.007	0.006	0.006	0.005
3	0	0	0	0	0.002	0.002	0.003	0.007	0.004	0.007	0.008	0.023	0.008	0.012	0.012	0.014	0.015	0.011	0.011	0.008	0.013	0.011	0.009	0.008	0.007
4	0	0	0	0	0.002	0.002	0.002	0.005	0.002	0.004	0.004	0.01	0.004	0.005	0.006	0.007	0.007	0.006	0.006	0.005	0.008	0.007	0.007	0.006	0.005
5	0	0	0	0	0.008	0.008	0.009	0.016	0.007	0.009	0.008	0.019	0.006	0.008	0.008	0.009	0.009	0.007	0.008	0.006	0.009	0.008	0.007	0.006	0.005
6	0	0	0	0	0.002	0.002	0.002	0.004	0.002	0.003	0.003	0.007	0.002	0.004	0.004	0.004	0.005	0.004	0.004	0.003	0.005	0.005	0.005	0.005	0.004
7	0	0	0	0	0.002	0.002	0.003	0.007	0.004	0.007	0.008	0.023	0.008	0.012	0.012	0.014	0.014	0.011	0.011	0.008	0.013	0.011	0.009	0.008	0.007
8	0	0	0	0	0.008	0.008	0.009	0.016	0.007	0.009	0.008	0.018	0.006	0.008	0.008	0.009	0.009	0.007	0.007	0.006	0.009	0.008	0.007	0.006	0.006
9	0	0	0	0	0.004	0.005	0.006	0.013	0.006	0.009	0.01	0.026	0.009	0.013	0.012	0.015	0.015	0.011	0.012	0.009	0.013	0.011	0.009	0.008	0.007
10	0	0	0	0	0.009	0.01	0.013	0.024	0.012	0.017	0.016	0.042	0.013	0.019	0.018	0.021	0.021	0.015	0.015	0.011	0.016	0.013	0.01	0.009	0.007
11	0	0	0	0	0.004	0.005	0.006	0.013	0.006	0.01	0.01	0.027	0.009	0.014	0.013	0.016	0.016	0.012	0.013	0.009	0.014	0.011	0.01	0.008	0.007
12	0	0	0	0	0.019	0.016	0.019	0.035	0.016	0.022	0.02	0.049	0.016	0.022	0.02	0.023	0.023	0.016	0.017	0.012	0.017	0.014	0.011	0.009	0.008
13	0	0	0	0	0.015	0.015	0.018	0.033	0.015	0.021	0.02	0.049	0.015	0.022	0.02	0.023	0.023	0.017	0.017	0.012	0.017	0.014	0.011	0.009	0.008
14	0	0	0	0	0.016	0.017	0.022	0.041	0.02	0.028	0.026	0.063	0.02	0.028	0.026	0.029	0.028	0.02	0.02	0.014	0.019	0.015	0.012	0.01	0.008
15	0	0	0	0	0.007	0.007	0.009	0.017	0.008	0.012	0.012	0.032	0.01	0.015	0.015	0.018	0.018	0.013	0.014	0.01	0.015	0.012	0.01	0.009	0.007
16	0	0	0	0	0.01	0.01	0.013	0.024	0.011	0.016	0.016	0.039	0.013	0.018	0.017	0.019	0.019	0.014	0.015	0.011	0.015	0.013	0.01	0.009	0.007
17	0	0	0	0	0.021	0.02	0.025	0.048	0.023	0.032	0.029	0.07	0.022	0.03	0.027	0.03	0.029	0.02	0.02	0.014	0.02	0.015	0.012	0.01	0.008
18	0	0	0	0	0.004	0.005	0.007	0.014	0.007	0.011	0.012	0.031	0.01	0.015	0.014	0.017	0.017	0.013	0.013	0.01	0.015	0.012	0.01	0.009	0.007
19	0	0	0	0	0.007	0.008	0.01	0.018	0.009	0.013	0.013	0.033	0.011	0.016	0.015	0.018	0.018	0.013	0.014	0.01	0.015	0.012	0.01	0.009	0.007
20	0	0	0	0	0.02	0.019	0.021	0.036	0.016	0.021	0.019	0.045	0.014	0.02	0.019	0.021	0.021	0.015	0.016	0.011	0.016	0.013	0.011	0.009	0.008
21	0	0	0	0	0.006	0.007	0.009	0.017	0.009	0.013	0.013	0.035	0.011	0.017	0.016	0.019	0.019	0.014	0.015	0.011	0.016	0.013	0.01	0.009	0.007
22	0	0	0	0	0.006	0.006	0.007	0.012	0.006	0.009	0.009	0.025	0.008	0.012	0.012	0.015	0.015	0.011	0.012	0.009	0.013	0.011	0.01	0.008	0.007

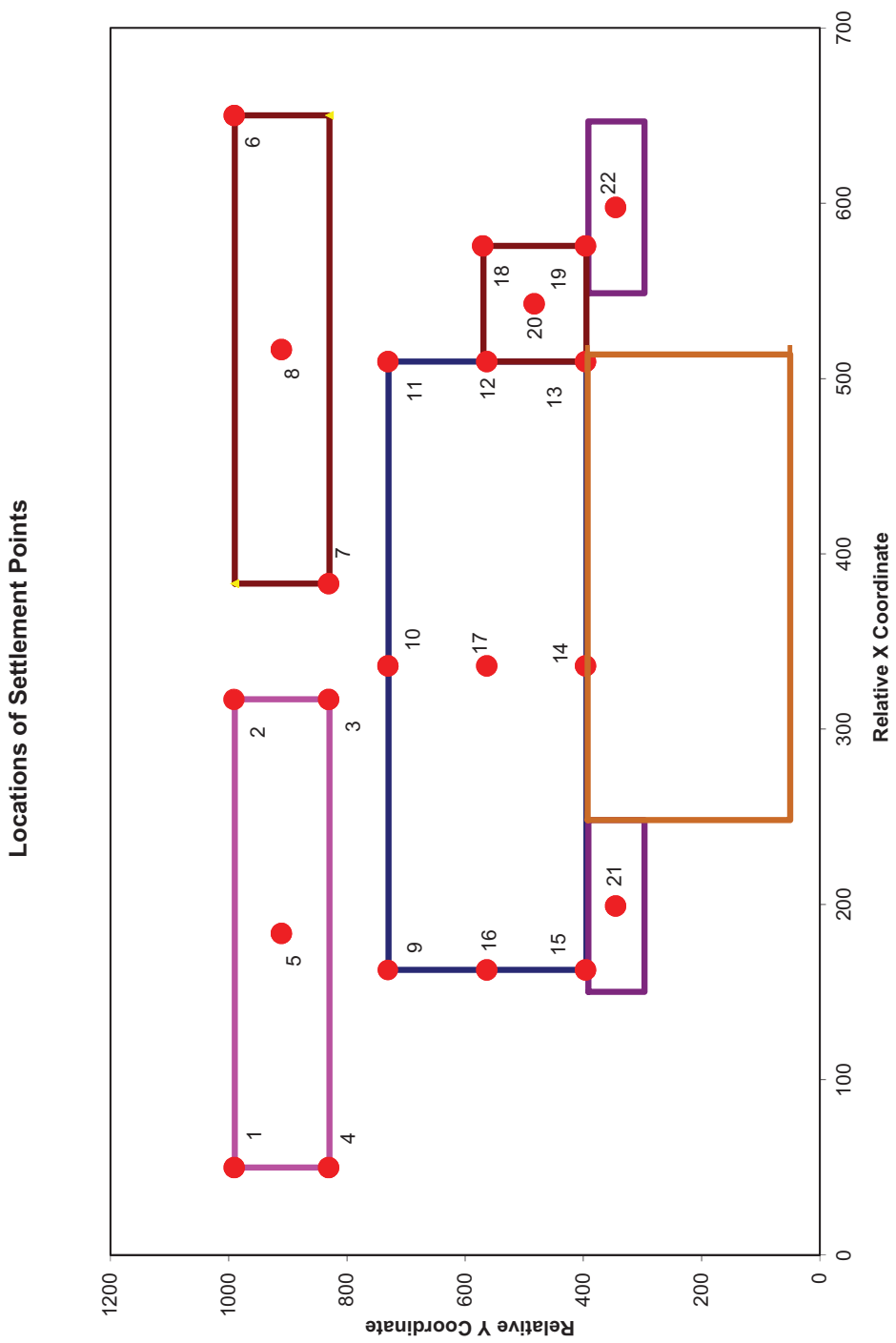
$Settle := TotalSettle(NSPP, NSPZ, SettleComp)$

Total Settlement Matrix (Inches)

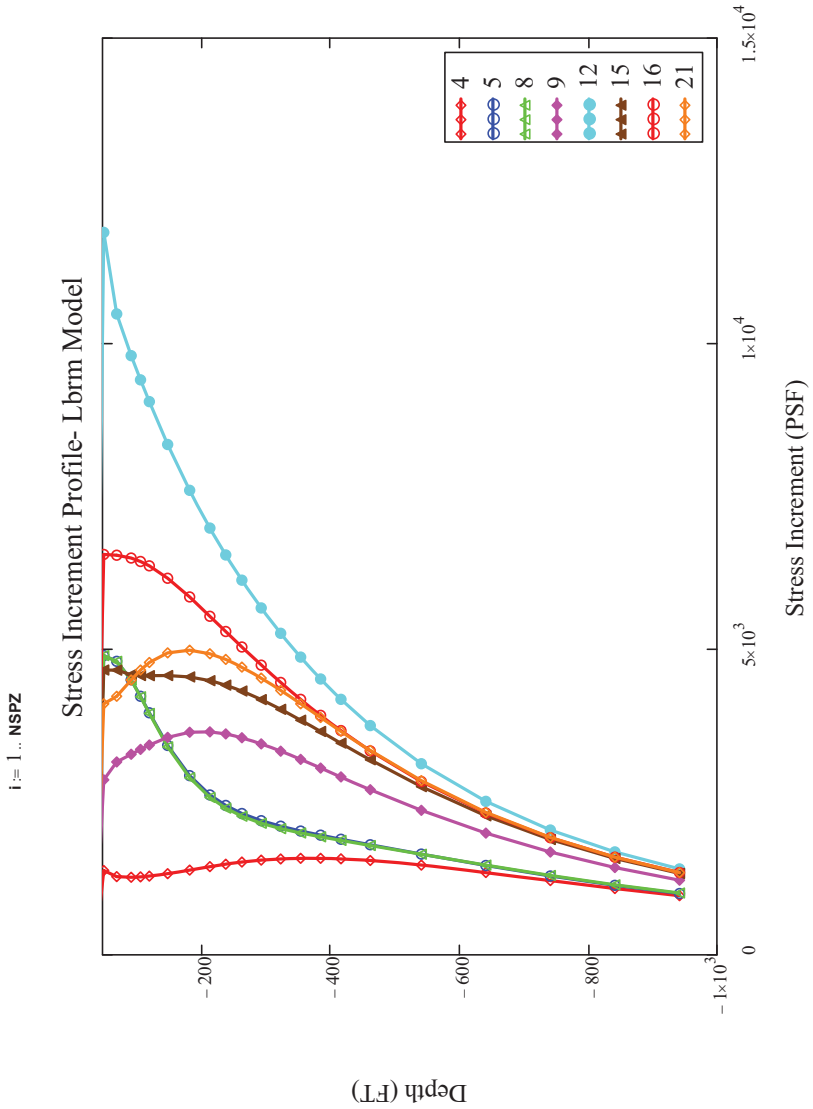
(Column index is the settlement point number)

$Settle^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.08	0.12	0.19	0.11	0.18	0.08	0.19	0.18	0.22	0.33	0.23	0.4	0.39	0.48	0.27	0.32	0.52	0.25	0.28	0.39	0.29	0.22



Settlement Calculation, Layered Method, Lower Bound Modulus, TXU


i := 1 .. NSPZ
Stress Increment Profile- Lbrm Model
Depth (FT)
Stress Increment (PSF)
-200
-400
-600
-800
-1×10^3
0
5×10^3
1×10^4
1.5×10^4
4
5
8
9
12
15
16
21

MODULUS AVERAGING

LAYER ID	LAYER CENTER DEPTH FT	THICKNESS FT	MODULUS PSF	$\sum_{i=1}^{n}\left(E_i \Big/ \sum_{j=1}^{i} h_j\right)$	$\sum_{i=1}^{n}\left(1 \Big/ \sum_{j=1}^{i} h_j\right)$
1.00	3.00	6.00	155,547,652		
2.00	15.00	18.00	155,547,652		
3.00	28.00	8.00	44,262,695		
4.00	36.00	8.00	48,648,130		
5.00	50.00	20.00	405,550,066	20277503	0.050
6.00	70.00	20.00	405,550,066	10138752	0.025
7.00	92.50	25.00	405,550,066	6239232	0.015
8.00	107.00	4.00	59,687,742	865040	0.014
9.00	120.50	23.00	313,510,454	3407722	0.011
10.00	149.00	34.00	585,032,604	4643116	0.008
11.00	183.00	34.00	205,855,826	1286599	0.006
12.00	214.50	29.00	72,539,100	383805	0.005
13.00	239.00	20.00	110,220,264	527370	0.005
14.00	264.00	30.00	110,220,264	461173	0.004
15.00	294.00	30.00	110,220,264	409741	0.004
16.00	324.00	30.00	117,958,712	394511	0.003
17.00	355.00	32.00	117,958,712	356371	0.003
18.00	386.00	30.00	110,901,382	307206	0.003
19.00	417.50	33.00	110,901,382	281476	0.003
20.00	463.00	58.00	378,267,514	836875	0.002
21.00	542.00	100.00	378,267,514	685267	0.002
22.00	642.00	100.00	378,267,514	580165	0.002
23.00	742.00	100.00	378,267,514	503015	0.001
24.00	842.00	100.00	378,267,514	443976	0.001
25.00	942.00	100.00	378,267,514	397340	0.001

$$E_{dw} = \frac{\sum_{i=1}^{n}\left(E_i \Big/ \sum_{j=1}^{i} h_j\right)}{\sum_{i=1}^{n}\left(1 \Big/ \sum_{j=1}^{i} h_j\right)} = \begin{array}{ll} 2199 & \text{KSI} \\ 316701108 & \text{PSF} \end{array}$$

Weighted Modulus Calculation

NON-LAYERED METHOD--BERM MODEL

WORKSHEET OF FOUNDATION SETTLEMENT ESTIMATION
Nonlayered Method, Berm Model, Mathcad Sheet for Cross Check against Excel Sheet

Reference: Soil Mechanics Principles and Application (1976), William Perloff and William Baron, Page 199-201.

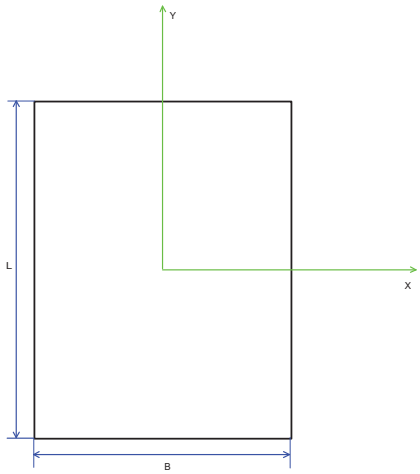


Figure 1. Notation for Rectanglular Loaded Area Shown in Plan View

The vertical Settlement of any point of the surface of an elastic half-space uniformly loaded over a rectangular area is expresses as

$$\delta(x, y, q, B, L) = C(x, y, B, L) \cdot \left[q \cdot B \cdot \frac{(1 - \mu)}{E_d} \right]$$

δ(x,y,q,B,L) = Vertical deformation at point (x,y) induced by a rectangular foundation.

q = unit load (psf)

B = foundation width (ft)

L = foundation length (ft)

μ= poisson's ratio

E_d = modulus of deformation of the rock foundation

C is a geometric factor which accounts for the shape of the rectangle shown in Figure B-1 and the position of the point for which the settlement is being calculated. C can be calculated based on following formulas:

$$A1(x,B) := 1 - 2\cdot\frac{x}{B} \qquad A2(x,B) := 1 + 2\cdot\frac{x}{B}$$

$$B1(y,B,L) := \frac{L}{B} - 2\cdot\frac{y}{B} \qquad B2(y,B,L) := \frac{L}{B} + 2\cdot\frac{y}{B}$$

$$C1(x,y,B,L) := B1(y,B,L)\cdot\ln\left[\frac{\left[\sqrt{(A1(x,B))^2 + (B1(y,B,L))^2} + A1(x,B)\right]}{\left[\sqrt{(A2(x,B))^2 + (B1(y,B,L))^2} - A2(x,B)\right]}\right]$$

$$C2(x,y,B,L) := B2(y,B,L)\cdot\ln\left[\frac{\left[\sqrt{(A1(x,B))^2 + (B2(y,B,L))^2} + A1(x,B)\right]}{\left[\sqrt{(A2(x,B))^2 + (B2(y,B,L))^2} - A2(x,B)\right]}\right]$$

$$C3(x,y,B,L) := A1(x,B)\cdot\ln\left[\frac{\left[\sqrt{(A1(x,B))^2 + (B1(y,B,L))^2} + B1(y,B,L)\right]}{\left[\sqrt{(A1(x,B))^2 + (B2(y,B,L))^2} - B2(y,B,L)\right]}\right]$$

$$C4(x,y,B,L) := A2(x,B)\cdot\ln\left[\frac{\left[\sqrt{(A2(x,B))^2 + (B1(y,B,L))^2} + B1(y,B,L)\right]}{\left[\sqrt{(A2(x,B))^2 + (B2(y,B,L))^2} - B2(y,B,L)\right]}\right]$$

$$C(x,y,B,L) := 0.159\cdot(C1(x,y,B,L) + C2(x,y,B,L) + C3(x,y,B,L) + C4(x,y,B,L))$$

DATA INPUT

Number of Loaded Area: $NLA := 7$

Number of Settlement Points in Plane: $NSPP := 22$

Elastic Modulus: $E := 316701108$ PSF

Poisson's Ratio: $\mu := 0.3$

Loaded Intensity (PSF) of Each Loaded Area:

13100	4900	4900	4000	4000	13100	10000

Loaded Area Coordinates (FT) of Rectangle Corners of Each Loaded Area:

	X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	112.67	679.5	459.67	679.5	459.67	344.92	112.67	344.92
2	0	939.59	267	939.59	267	779.59	0	779.59
3	333.08	939.59	600.08	939.59	600.08	779.59	333.08	779.59
4	100.17	341.67	198.17	341.67	198.17	246.67	100.17	246.67
5	498.67	341.67	596.67	341.67	596.67	246.67	498.67	246.67
6	459.67	519	525.67	519	525.67	344.92	459.67	344.92
	198.17	342.67	463.67	342.67	463.67	0	198.17	0

Coordinates of Settlement Points (FT)

X	Y
0	940.59
267	940.59
267	780.59
0	780.59
133.5	860.59
600.08	940.59
333.08	780.59
466.58	860.59
112.67	680.5
286.17	680.5
459.67	680.5
459.67	513.21
459.67	345.92
286.17	345.92
112.67	345.92
112.67	513.21
286.17	513.21
525.67	520
525.67	345.92
492.67	432.96
149.17	295.17
547.67	295.17

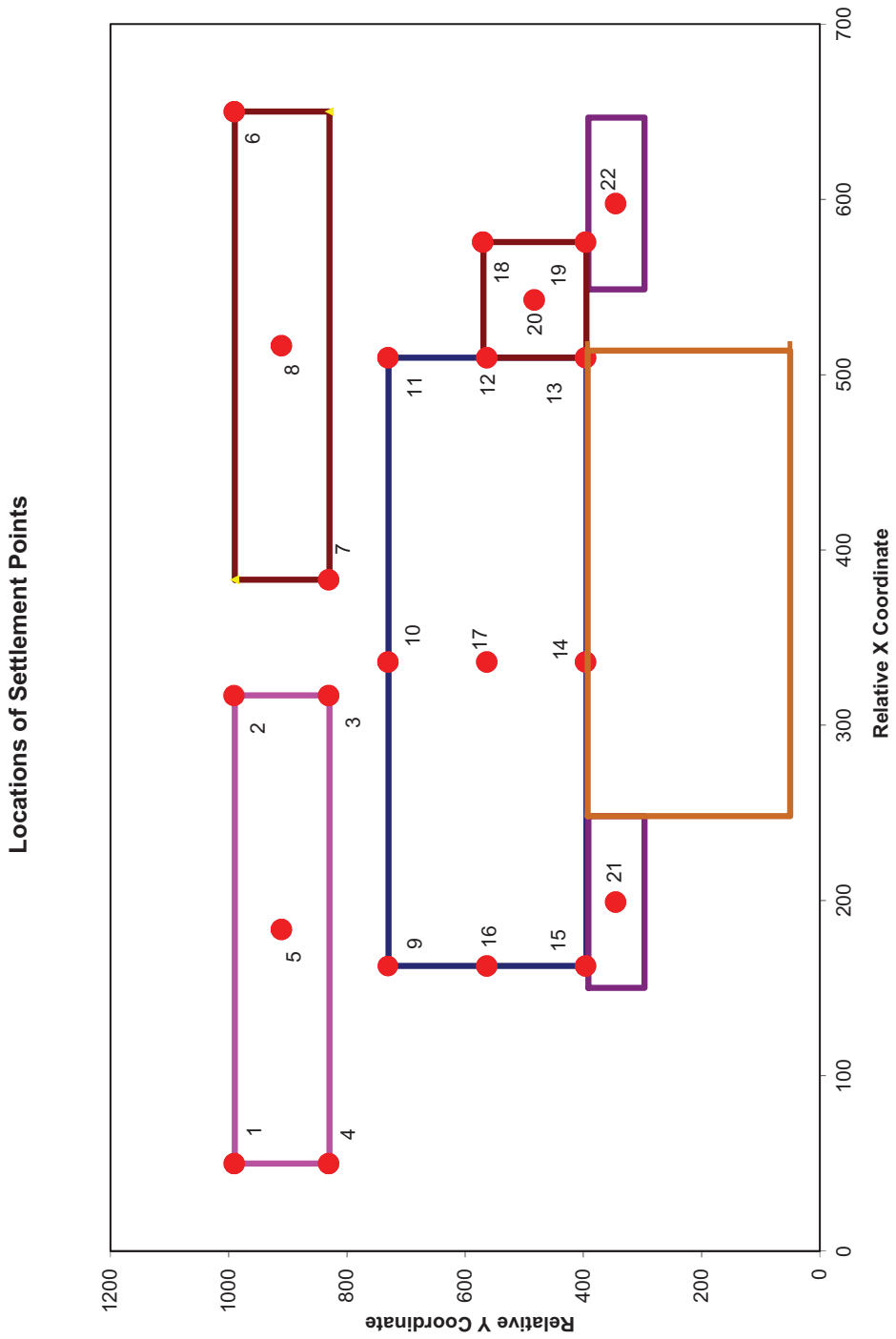
$$X := \left| \begin{array}{l} \text{for } i \in 1 .. NSPP \\ \quad X_i \leftarrow CSP_{i,1} \\ X \end{array} \right. \qquad Y := \left| \begin{array}{l} \text{for } i \in 1 .. NSPP \\ \quad Y_i \leftarrow CSP_{i,2} \\ Y \end{array} \right.$$

Settlement Matrix (inches): Row index is settlement point number

ST =

	1
1	0.06
2	0.07
3	0.09
4	0.07
5	0.08
6	0.06
7	0.09
8	0.08
9	0.1
10	0.13
11	0.1
12	0.15
13	0.15
14	0.17
15	0.12
16	0.13
17	0.17
18	0.11
19	0.12
20	0.14
21	0.12
22	0.1

Appendix A



Settlement Calculation, Non-Layered Method, Best Estimated Modulus, TXU

MODULUS AVERAGING

LAYER ID	LAYER CENTER DEPTH FT	THICKNESS FT	MODULUS PSF	$\sum_{i=1}^{n}\left(E_i \Big/ \sum_{j=1}^{i} h_j\right)$	$\sum_{i=1}^{n}\left(1 \Big/ \sum_{j=1}^{i} h_j\right)$
1.00	3.00	6.00	91,508,416		
2.00	15.00	18.00	91,508,416		
3.00	28.00	8.00	11,650,143		
4.00	36.00	8.00	11,650,143		
5.00	50.00	20.00	139,212,424	6960621	0.050
6.00	70.00	20.00	139,212,424	3480311	0.025
7.00	92.50	25.00	139,212,424	2141730	0.015
8.00	107.00	4.00	11,650,143	168843	0.014
9.00	120.50	23.00	139,212,424	1513179	0.011
10.00	149.00	34.00	139,212,424	1104861	0.008
11.00	183.00	34.00	139,212,424	870078	0.006
12.00	214.50	29.00	44,754,165	236795	0.005
13.00	239.00	20.00	91,866,353	439552	0.005
14.00	264.00	30.00	91,866,353	384378	0.004
15.00	294.00	30.00	91,866,353	341511	0.004
16.00	324.00	30.00	75,174,273	251419	0.003
17.00	355.00	32.00	75,174,273	227113	0.003
18.00	386.00	30.00	90,209,128	249887	0.003
19.00	417.50	33.00	90,209,128	228957	0.003
20.00	463.00	58.00	200,298,272	443138	0.002
21.00	542.00	100.00	200,298,272	362859	0.002
22.00	642.00	100.00	200,298,272	307206	0.002
23.00	742.00	100.00	200,298,272	266354	0.001
24.00	842.00	100.00	200,298,272	235092	0.001
25.00	942.00	100.00	200,298,272	210397	0.001

$$E_{dw} = \frac{\sum_{i=1}^{n}\left(E_i \Big/ \sum_{j=1}^{i} h_j\right)}{\sum_{i=1}^{n}\left(1 \Big/ \sum_{j=1}^{i} h_j\right)} = \begin{array}{ll} 841 & \text{KSI} \\ 121071402 & \text{PSF} \end{array}$$

Weighted Modulus Calculation

NON-LAYERED METHOD--LBRM MODEL

WORKSHEET OF FOUNDATION SETTLEMENT ESTIMATION
Nonlayered Method, Lbrm Model, Mathcad Sheet for Cross Check against Excel Sheet

Reference: Soil Mechanics Principles and Application (1976), William Perloff and William Baron, Page 199-201.

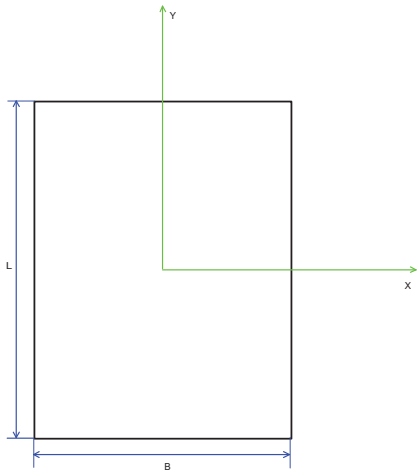


Figure 1. Notation for Rectanglular Loaded Area Shown in Plan View

The vertical Settlement of any point of the surface of an elastic half-space uniformly loaded over a rectangular area is expresses as

$$\delta(x, y, q, B, L) = C(x, y, B, L) \cdot \left[q \cdot B \cdot \frac{(1 - \mu)}{E_d} \right]$$

δ(x,y,q,B,L) = Vertical deformation at point (x,y) induced by a rectangular foundation.

q = unit load (psf)

B = foundation width (ft)

L = foundation length (ft)

μ= poisson's ratio

E_d = modulus of deformation of the rock foundation

C is a geometric factor which accounts for the shape of the rectangle shown in Figure B-1 and the position of the point for which the settlement is being calculated. C can be calculated based on following formulas:

$$A1(x,B) := 1 - 2\cdot\frac{x}{B} \qquad A2(x,B) := 1 + 2\cdot\frac{x}{B}$$

$$B1(y,B,L) := \frac{L}{B} - 2\cdot\frac{y}{B} \qquad B2(y,B,L) := \frac{L}{B} + 2\cdot\frac{y}{B}$$

$$C1(x,y,B,L) := B1(y,B,L)\cdot\ln\left[\frac{\left[\sqrt{(A1(x,B))^2 + (B1(y,B,L))^2} + A1(x,B)\right]}{\left[\sqrt{(A2(x,B))^2 + (B1(y,B,L))^2} - A2(x,B)\right]}\right]$$

$$C2(x,y,B,L) := B2(y,B,L)\cdot\ln\left[\frac{\left[\sqrt{(A1(x,B))^2 + (B2(y,B,L))^2} + A1(x,B)\right]}{\left[\sqrt{(A2(x,B))^2 + (B2(y,B,L))^2} - A2(x,B)\right]}\right]$$

$$C3(x,y,B,L) := A1(x,B)\cdot\ln\left[\frac{\left[\sqrt{(A1(x,B))^2 + (B1(y,B,L))^2} + B1(y,B,L)\right]}{\left[\sqrt{(A1(x,B))^2 + (B2(y,B,L))^2} - B2(y,B,L)\right]}\right]$$

$$C4(x,y,B,L) := A2(x,B)\cdot\ln\left[\frac{\left[\sqrt{(A2(x,B))^2 + (B1(y,B,L))^2} + B1(y,B,L)\right]}{\left[\sqrt{(A2(x,B))^2 + (B2(y,B,L))^2} - B2(y,B,L)\right]}\right]$$

$$C(x,y,B,L) := 0.159\cdot(C1(x,y,B,L) + C2(x,y,B,L) + C3(x,y,B,L) + C4(x,y,B,L))$$

DATA INPUT

Number of Loaded Area: $NLA := 7$

Number of Settlement Points in Plane: $NSPP := 22$

Elastic Modulus: $E := 121071402$ PSF

Poisson's Ratio: $\mu := 0.3$

Loaded Intensity (PSF) of Each Loaded Area:

13100	4900	4900	4000	4000	13100	10000

Loaded Area Coordinates (FT) of Rectangle Corners of Each Loaded Area:

	X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	112.67	679.5	459.67	679.5	459.67	344.92	112.67	344.92
2	0	939.59	267	939.59	267	779.59	0	779.59
3	333.08	939.59	600.08	939.59	600.08	779.59	333.08	779.59
4	100.17	341.67	198.17	341.67	198.17	246.67	100.17	246.67
5	498.67	341.67	596.67	341.67	596.67	246.67	498.67	246.67
6	459.67	519	525.67	519	525.67	344.92	459.67	344.92
7	198.17	342.67	463.67	342.67	463.67	0	198.17	0

Coordinates of Settlement Points (FT)

X	Y
0	940.59
267	940.59
267	780.59
0	780.59
133.5	860.59
600.08	940.59
333.08	780.59
466.58	860.59
112.67	680.5
286.17	680.5
459.67	680.5
459.67	513.21
459.67	345.92
286.17	345.92
112.67	345.92
112.67	513.21
286.17	513.21
525.67	520
525.67	345.92
492.67	432.96
149.17	295.17
547.67	295.17

$$X := \left| \begin{array}{l} \text{for } i \in 1 .. NSPP \\ \quad X_i \leftarrow CSP_{i,1} \\ X \end{array} \right.$$

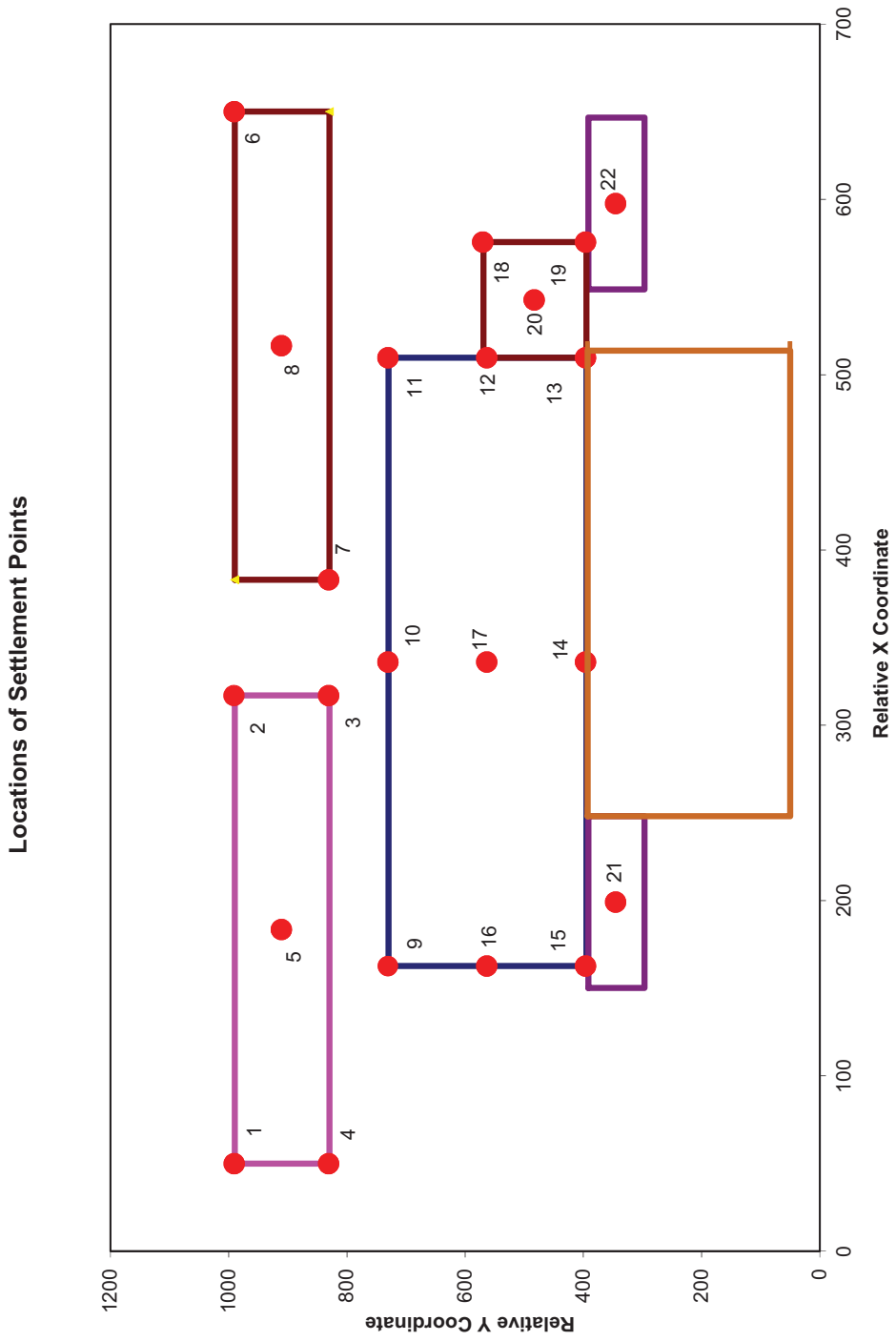
$$Y := \left| \begin{array}{l} \text{for } i \in 1 .. NSPP \\ \quad Y_i \leftarrow CSP_{i,2} \\ Y \end{array} \right.$$

Settlement Matrix (inches): Row index is settlement point number

ST =

	1
1	0.15
2	0.18
3	0.24
4	0.18
5	0.22
6	0.15
7	0.24
8	0.22
9	0.26
10	0.34
11	0.27
12	0.39
13	0.38
14	0.44
15	0.3
16	0.33
17	0.45
18	0.28
19	0.3
20	0.38
21	0.3
22	0.26

Appendix A



Settlement Calculation, Non-Layered Method, Lower Bound Modulus, TXU

APPENDIX B

Rebound Calculations

Layered Method Using Best Estimated Rock Modulus (BERM) Model (Excel)
Pages 2 through 7
Non-layered Method Using Best Estimated Rock Modulus (BERM) Model (Excel)
Pages 8 through **16**
Layered Method Using Best Estimated Rock Modulus (BERM) Model (Mathcad)
Pages **17** through 24
Non-layered Method Best Estimated Rock Modulus (BERM) Model (Mathcad)
Pages 25 through 30

REBOUND ANALYSIS FOR ELASTIC MATERIALS
Layered Method, BERM Model

METHODOLOGY

This worksheet has been developed to calculate elastic rebound induced by foundation excavation. The soils below foundations are considered as layered elastic medium and the stress decrement at each layer center due to a rectanglar uniformly unloaded area at or below ground surface is computed by classic Boussinesq solution. The rebound for each layer is calculated using the vertical stress decrement and elastic modulus of the layer, and total rebound is obtained by summing all layer rebound in the influenced zone.

Stress Decrement:

The equation of Boussinesq solution to compute the stress decrement under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given unloaded area, superposition of rectanglar areas covering the unloaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is unload intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Rebound Calculation:

The rebound in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Rebound:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layers influenced by foundation exacavation.

SUMMARY OF INPUT

Number of Unloaded Areas= 7 Number of Soil Layers= 25 Number of Rebound Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

Unload Unit ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	UNLOAD UNIT CORNER COORDINATES (FT)							
			X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	5.7	40.0	112.7	679.5	459.7	679.5	459.7	344.9	112.7	344.9
2	5.7	40.0	0.0	939.6	267.0	939.6	267.0	779.6	0.0	779.6
3	5.7	40.0	333.1	939.6	600.1	939.6	600.1	779.6	333.1	779.6
4	5.7	40.0	100.2	341.7	198.2	341.7	198.2	246.7	100.2	246.7
5	5.7	40.0	498.7	341.7	596.7	341.7	596.7	246.7	498.7	246.7
6	5.7	40.0	459.7	519.0	525.7	519.0	525.7	344.9	459.7	344.9
7	5.7	40.0	198.2	342.7	463.7	342.7	463.7	0.0	198.2	0.0

REBOUND POINT COORDINATES					
ID	X	Y	ID	X	Y
1	0.0	940.6	2	267.0	940.6
3	267.0	780.6	4	0.0	780.6
5	133.5	860.6	6	600.1	940.6
7	333.1	780.6	8	466.6	860.6
9	112.7	680.5	10	286.2	680.5
11	459.7	680.5	12	459.7	513.2
13	459.7	345.9	14	286.2	345.9
15	112.7	345.9	16	112.7	513.2
17	286.2	513.2	18	525.7	520.0
19	525.7	345.9	20	492.7	433.0
21	149.2	295.2	22	547.7	295.2

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
19	417.50	33.00	110901	20	463.00	58.00	378268
21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Depth (FT)	Stress Decrement Contributed by All Unloaded Areas at Each Rebound Points, KSF																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	1.24	1.24	1.60	1.60	5.66	1.24	1.60	5.66	1.24	2.48	1.24	5.12	4.43	4.93	2.94	2.83	5.67	1.24	3.04	5.64	5.65	5.64
70.00	1.35	1.40	1.54	1.48	5.55	1.35	1.54	5.55	1.38	2.73	1.38	4.54	4.46	5.39	3.17	2.83	5.65	1.40	3.54	5.22	5.30	5.09
92.50	1.37	1.52	1.70	1.45	5.18	1.37	1.70	5.18	1.49	2.82	1.50	4.25	4.47	5.45	3.03	2.82	5.60	1.54	3.40	4.58	4.62	4.06
107.00	1.36	1.60	1.84	1.43	4.85	1.36	1.84	4.85	1.57	2.87	1.59	4.09	4.43	5.42	2.95	2.80	5.52	1.64	3.29	4.24	4.22	3.50
120.50	1.34	1.66	1.98	1.42	4.51	1.34	1.97	4.51	1.65	2.91	1.68	3.95	4.36	5.37	2.87	2.78	5.44	1.73	3.18	3.99	3.92	3.12
149.00	1.29	1.74	2.22	1.39	3.81	1.29	2.22	3.80	1.81	2.99	1.86	3.68	4.15	5.17	2.73	2.73	5.18	1.87	2.98	3.59	3.47	2.62
183.00	1.21	1.77	2.39	1.35	3.13	1.21	2.38	3.11	1.95	3.01	2.03	3.40	3.86	4.85	2.59	2.64	4.81	1.98	2.77	3.27	3.13	2.33
214.50	1.14	1.74	2.44	1.32	2.65	1.13	2.43	2.64	2.00	2.97	2.11	3.18	3.58	4.51	2.48	2.54	4.44	2.02	2.61	3.04	2.91	2.19
239.00	1.08	1.69	2.43	1.29	2.37	1.08	2.42	2.35	2.01	2.91	2.13	3.03	3.38	4.24	2.40	2.46	4.15	2.03	2.50	2.89	2.76	2.11
264.00	1.03	1.64	2.38	1.26	2.14	1.03	2.37	2.13	2.00	2.82	2.13	2.88	3.18	3.97	2.31	2.38	3.87	2.02	2.39	2.75	2.63	2.04
294.00	0.98	1.57	2.30	1.22	1.93	0.97	2.29	1.91	1.96	2.70	2.09	2.72	2.96	3.65	2.22	2.28	3.56	1.99	2.27	2.59	2.49	1.96
324.00	0.93	1.50	2.20	1.19	1.77	0.93	2.19	1.75	1.91	2.57	2.04	2.56	2.76	3.36	2.12	2.18	3.28	1.94	2.16	2.44	2.35	1.88
355.00	0.89	1.43	2.08	1.15	1.63	0.89	2.08	1.61	1.84	2.43	1.97	2.41	2.56	3.08	2.02	2.08	3.01	1.88	2.05	2.30	2.21	1.80
386.00	0.86	1.36	1.97	1.12	1.51	0.85	1.96	1.50	1.76	2.28	1.89	2.27	2.38	2.82	1.92	1.98	2.77	1.82	1.94	2.17	2.08	1.72
417.50	0.82	1.29	1.85	1.08	1.42	0.82	1.85	1.41	1.68	2.15	1.80	2.13	2.21	2.59	1.82	1.88	2.56	1.75	1.83	2.04	1.95	1.64
463.00	0.78	1.20	1.70	1.03	1.30	0.78	1.69	1.29	1.57	1.95	1.67	1.95	1.99	2.29	1.68	1.74	2.28	1.64	1.69	1.86	1.78	1.53
542.00	0.73	1.06	1.45	0.95	1.13	0.73	1.45	1.13	1.38	1.66	1.46	1.66	1.67	1.87	1.46	1.51	1.89	1.45	1.46	1.60	1.52	1.34
642.00	0.66	0.91	1.20	0.85	0.96	0.66	1.21	0.96	1.16	1.36	1.23	1.37	1.36	1.48	1.22	1.27	1.51	1.23	1.22	1.32	1.26	1.13
742.00	0.60	0.78	1.01	0.75	0.82	0.60	1.01	0.83	0.99	1.12	1.04	1.13	1.11	1.20	1.03	1.06	1.22	1.04	1.02	1.10	1.05	0.96
842.00	0.54	0.68	0.85	0.66	0.71	0.55	0.85	0.72	0.84	0.93	0.88	0.95	0.93	0.98	0.87	0.90	1.01	0.88	0.87	0.92	0.88	0.82
942.00	0.49	0.59	0.72	0.59	0.62	0.50	0.72	0.63	0.72	0.79	0.75	0.80	0.78	0.82	0.74	0.76	0.84	0.75	0.74	0.78	0.75	0.70

Appendix B

REBOUND DISTRIBUTION (INCHES)

Rebound Point Layer ID	Rebound Contributed by All Unloaded Areas for Each Layer at Each Rebound Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00
12	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00
14	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.04**	**0.06**	**0.08**	**0.05**	**0.09**	**0.04**	**0.08**	**0.09**	**0.07**	**0.10**	**0.08**	**0.11**	**0.11**	**0.14**	**0.09**	**0.09**	**0.14**	**0.07**	**0.09**	**0.10**	**0.10**	**0.08**

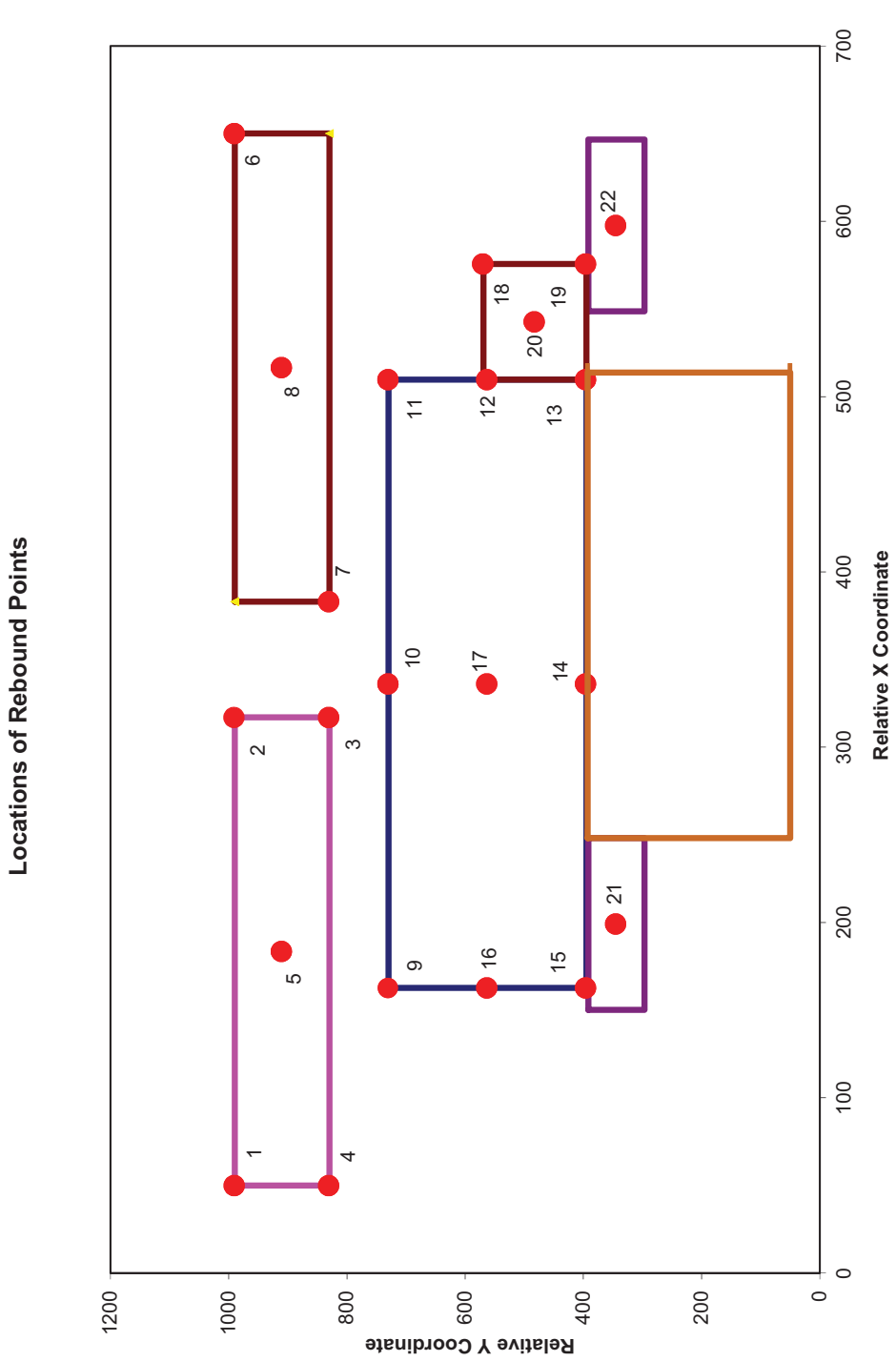
Appendix B

Rebound Calculation, Best Estimated Rock Modulus, TXU

SUMMARY OF REBOUND

Rebound Point	X	Y	Rebound Inches	Rebound Point	X	Y	Rebound Inches
1	0.0	940.6	0.04	2	267.0	940.6	0.06
3	267.0	780.6	0.08	4	0.0	780.6	0.05
5	133.5	860.6	0.09	6	600.1	940.6	0.04
7	333.1	780.6	0.08	8	466.6	860.6	0.09
9	112.7	680.5	0.07	10	286.2	680.5	0.10
11	459.7	680.5	0.08	12	459.7	513.2	0.11
13	459.7	345.9	0.11	14	286.2	345.9	0.14
15	112.7	345.9	0.09	16	112.7	513.2	0.09
17	286.2	513.2	0.14	18	525.7	520.0	0.07
19	525.7	345.9	0.09	20	492.7	433.0	0.10
21	149.2	295.2	0.10	22	547.7	295.2	0.08

Appendix B



Rebound Calculation, Layered Method, Best Estimated Modulus, TXU

MODULUS AVERAGING

LAYER ID	LAYER CENTER DEPTH FT	THICKNESS FT	MODULUS PSF	$\sum_{i=1}^{n}\left(E_i \Big/ \sum_{j=1}^{i} h_j\right)$	$\sum_{i=1}^{n}\left(1 \Big/ \sum_{j=1}^{i} h_j\right)$
1.00	3.00	6.00	155,547,652		
2.00	15.00	18.00	155,547,652		
3.00	28.00	8.00	44,262,695		
4.00	36.00	8.00	48,648,130		
5.00	50.00	20.00	405,550,066	20277503	0.050
6.00	70.00	20.00	405,550,066	10138752	0.025
7.00	92.50	25.00	405,550,066	6239232	0.015
8.00	107.00	4.00	59,687,742	865040	0.014
9.00	120.50	23.00	313,510,454	3407722	0.011
10.00	149.00	34.00	585,032,604	4643116	0.008
11.00	183.00	34.00	205,855,826	1286599	0.006
12.00	214.50	29.00	72,539,100	383805	0.005
13.00	239.00	20.00	110,220,264	527370	0.005
14.00	264.00	30.00	110,220,264	461173	0.004
15.00	294.00	30.00	110,220,264	409741	0.004
16.00	324.00	30.00	117,958,712	394511	0.003
17.00	355.00	32.00	117,958,712	356371	0.003
18.00	386.00	30.00	110,901,382	307206	0.003
19.00	417.50	33.00	110,901,382	281476	0.003
20.00	463.00	58.00	378,267,514	836875	0.002
21.00	542.00	100.00	378,267,514	685267	0.002
22.00	642.00	100.00	378,267,514	580165	0.002
23.00	742.00	100.00	378,267,514	503015	0.001
24.00	842.00	100.00	378,267,514	443976	0.001
25.00	942.00	100.00	378,267,514	397340	0.001

$$E_{dw} = \frac{\sum_{i=1}^{n}\left(E_i \Big/ \sum_{j=1}^{i} h_j\right)}{\sum_{i=1}^{n}\left(1 \Big/ \sum_{j=1}^{i} h_j\right)} = \begin{array}{ll} 2199 & \text{KSI} \\ 316701108 & \text{PSF} \end{array}$$

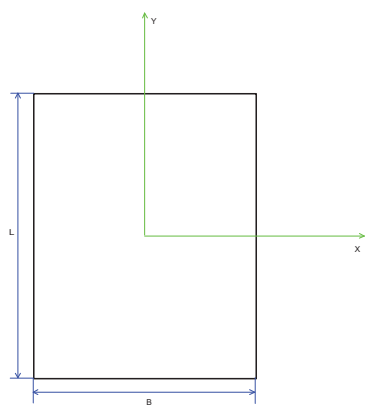
Weighted Modulus Calculation

NON-LAYERED METHOD--BERM MODEL

REBOUND ANALYSIS FOR ELASTIC MATERIALS (NON-LAYERED) BERM MODEL

Reference: Soil Mechanics Principles and Application, William Perloff and William Baron,1976,Page 199-201

METHODOLOGY:



The vertical rebound of any point of the surface of an elastic half-space uniformly unloaded over a rectangular area is expressed as:

$$\delta(x,y) = C(x,y)\frac{qB(1-\mu)}{E}$$

where d(x,y) is vertical rebound at point (x,y) by a rectangular foundation, q is the unload intensity, B foundation width, L foundation length, p is poisson's ratio, E is modulus of deformation of the bearing rock. And C(x,y) is a geometric factor which accounts for shape of the rectangle shown in Figure 1 and the the position of the point for which the rebound is being calculated. C can be calculated based on following formulas:

$$C(x,y) = \frac{1}{2\pi}\left(C_1 + C_2 + C_3 + C_4\right)$$

$$C_1 = B_1 \ln\left(\frac{\sqrt{A_1^2 + B_1^2} + A_1}{\sqrt{A_2^2 + B_1^2} - A_2}\right) \qquad C_2 = B_2 \ln\left(\frac{\sqrt{A_1^2 + B_2^2} + A_1}{\sqrt{A_2^2 + B_2^2} - A_2}\right)$$

$$C_3 = A_1 \ln\left(\frac{\sqrt{A_1^2 + B_1^2} + B_1}{\sqrt{A_1^2 + B_2^2} - B_2}\right) \qquad C_4 = A_2 \ln\left(\frac{\sqrt{A_2^2 + B_1^2} + B_1}{\sqrt{A_2^2 + B_2^2} - B_2}\right)$$

$$A_1 = 1 - \frac{2x}{B} \qquad A_2 = 1 + \frac{2x}{B} \qquad B_1 = \frac{L}{B} - \frac{2y}{B} \qquad B_2 = \frac{L}{B} + \frac{2y}{B}$$

Appendix B

INPUT SUMMARY:

NUMBER OF UNUNLOADED AREAS= 7 POISSON'S RATIO= 0.30

NUMBER OF REBOUND POINTS= 22 ELASTIC MODULUS= 316701 KSF

UNLOAD UNIT ID	UNLOAD INTENSITY PSF	UNLOAD UNIT CORNER COORDINATES (FT)							
		X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	5670.0	112.7	679.5	459.7	679.5	459.7	344.9	112.7	344.9
2	5670.0	0.0	939.6	267.0	939.6	267.0	779.6	0.0	779.6
3	5670.0	333.1	939.6	600.1	939.6	600.1	779.6	333.1	779.6
4	5670.0	100.2	341.7	198.2	341.7	198.2	246.7	100.2	246.7
5	5670.0	498.7	341.7	596.7	341.7	596.7	246.7	498.7	246.7
6	5670.0	459.7	519.0	525.7	519.0	525.7	344.9	459.7	344.9
7	5670.0	198.2	342.7	463.7	342.7	463.7	0.0	198.2	0.0

REBOUND POINT COORDINATES								
ID	X	Y	ID	X	Y	ID	X	Y
1	0.0	940.6	2	267.0	940.6	3	267.0	780.6
4	0.0	780.6	5	133.5	860.6	6	600.1	940.6
7	333.1	780.6	8	466.6	860.6	9	112.7	680.5
10	286.2	680.5	11	459.7	680.5	12	459.7	513.2
13	459.7	345.9	14	286.2	345.9	15	112.7	345.9
16	112.7	513.2	17	286.2	513.2	18	525.7	520.0
19	525.7	345.9	20	492.7	433.0	21	149.2	295.2
22	547.7	295.2						

OUTPUT SUMMARY:

CALCULATION BASED ON UNLOADED AREA 1						CALCULATION BASED ON UNLOADED AREA 2					
Rebound ID	General Coordinates		Local Coordinates		Rebound Component	Rebound ID	General Coordinates		Local Coordinates		Rebound Component
	X	Y	X'	Y'			X	Y	X'	Y'	
1	0.0	940.6	428.4	-286.2	0.001	1	0.0	940.6	81.0	-133.5	0.001
2	267.0	940.6	428.4	-19.2	0.001	2	267.0	940.6	81.0	133.5	0.001
3	267.0	780.6	268.4	-19.2	0.002	3	267.0	780.6	-79.0	133.5	0.001
4	0.0	780.6	268.4	-286.2	0.001	4	0.0	780.6	-79.0	-133.5	0.001
5	133.5	860.6	348.4	-152.7	0.001	5	133.5	860.6	1.0	0.0	0.003
6	600.1	940.6	428.4	313.9	0.001	6	600.1	940.6	81.0	466.6	0.000
7	333.1	780.6	268.4	46.9	0.002	7	333.1	780.6	-79.0	199.6	0.001
8	466.6	860.6	348.4	180.4	0.001	8	466.6	860.6	1.0	333.1	0.001
9	112.7	680.5	168.3	-173.5	0.002	9	112.7	680.5	-179.1	-20.8	0.001
10	286.2	680.5	168.3	0.0	0.003	10	286.2	680.5	-179.1	152.7	0.001
11	459.7	680.5	168.3	173.5	0.002	11	459.7	680.5	-179.1	326.2	0.000
12	459.7	513.2	1.0	173.5	0.003	12	459.7	513.2	-346.4	326.2	0.000
13	459.7	345.9	-166.3	173.5	0.002	13	459.7	345.9	-513.7	326.2	0.000
14	286.2	345.9	-166.3	0.0	0.003	14	286.2	345.9	-513.7	152.7	0.000
15	112.7	345.9	-166.3	-173.5	0.002	15	112.7	345.9	-513.7	-20.8	0.000
16	112.7	513.2	1.0	-173.5	0.003	16	112.7	513.2	-346.4	-20.8	0.000
17	286.2	513.2	1.0	0.0	0.005	17	286.2	513.2	-346.4	152.7	0.000
18	525.7	520.0	7.8	239.5	0.002	18	525.7	520.0	-339.6	392.2	0.000
19	525.7	345.9	-166.3	239.5	0.002	19	525.7	345.9	-513.7	392.2	0.000
20	492.7	433.0	-79.2	206.5	0.002	20	492.7	433.0	-426.6	359.2	0.000
21	149.2	295.2	-217.0	-137.0	0.002	21	149.2	295.2	-564.4	15.7	0.000
22	547.7	295.2	-217.0	261.5	0.001	22	547.7	295.2	-564.4	414.2	0.000

Appendix B

CALCULATION BASED ON UNLOADED AREA 3						CALCULATION BASED ON UNLOADED AREA 4					
Rebound ID	General Coordinates		Local Coordinates		Rebound Component	Rebound ID	General Coordinates		Local Coordinates		Rebound Component
	X	Y	X'	Y'			X	Y	X'	Y'	
1	0.0	940.6	81.0	-466.6	0.000	1	0.0	940.6	646.4	-149.2	0.000
2	267.0	940.6	81.0	-199.6	0.001	2	267.0	940.6	646.4	117.8	0.000
3	267.0	780.6	-79.0	-199.6	0.001	3	267.0	780.6	486.4	117.8	0.000
4	0.0	780.6	-79.0	-466.6	0.000	4	0.0	780.6	486.4	-149.2	0.000
5	133.5	860.6	1.0	-333.1	0.001	5	133.5	860.6	566.4	-15.7	0.000
6	600.1	940.6	81.0	133.5	0.001	6	600.1	940.6	646.4	450.9	0.000
7	333.1	780.6	-79.0	-133.5	0.001	7	333.1	780.6	486.4	183.9	0.000
8	466.6	860.6	1.0	0.0	0.003	8	466.6	860.6	566.4	317.4	0.000
9	112.7	680.5	-179.1	-353.9	0.000	9	112.7	680.5	386.3	-36.5	0.000
10	286.2	680.5	-179.1	-180.4	0.001	10	286.2	680.5	386.3	137.0	0.000
11	459.7	680.5	-179.1	-6.9	0.001	11	459.7	680.5	386.3	310.5	0.000
12	459.7	513.2	-346.4	-6.9	0.000	12	459.7	513.2	219.0	310.5	0.000
13	459.7	345.9	-513.7	-6.9	0.000	13	459.7	345.9	51.8	310.5	0.000
14	286.2	345.9	-513.7	-180.4	0.000	14	286.2	345.9	51.8	137.0	0.000
15	112.7	345.9	-513.7	-353.9	0.000	15	112.7	345.9	51.8	-36.5	0.001
16	112.7	513.2	-346.4	-353.9	0.000	16	112.7	513.2	219.0	-36.5	0.000
17	286.2	513.2	-346.4	-180.4	0.000	17	286.2	513.2	219.0	137.0	0.000
18	525.7	520.0	-339.6	59.1	0.000	18	525.7	520.0	225.8	376.5	0.000
19	525.7	345.9	-513.7	59.1	0.000	19	525.7	345.9	51.8	376.5	0.000
20	492.7	433.0	-426.6	26.1	0.000	20	492.7	433.0	138.8	343.5	0.000
21	149.2	295.2	-564.4	-317.4	0.000	21	149.2	295.2	1.0	0.0	0.001
22	547.7	295.2	-564.4	81.1	0.000	22	547.7	295.2	1.0	398.5	0.000

Appendix B

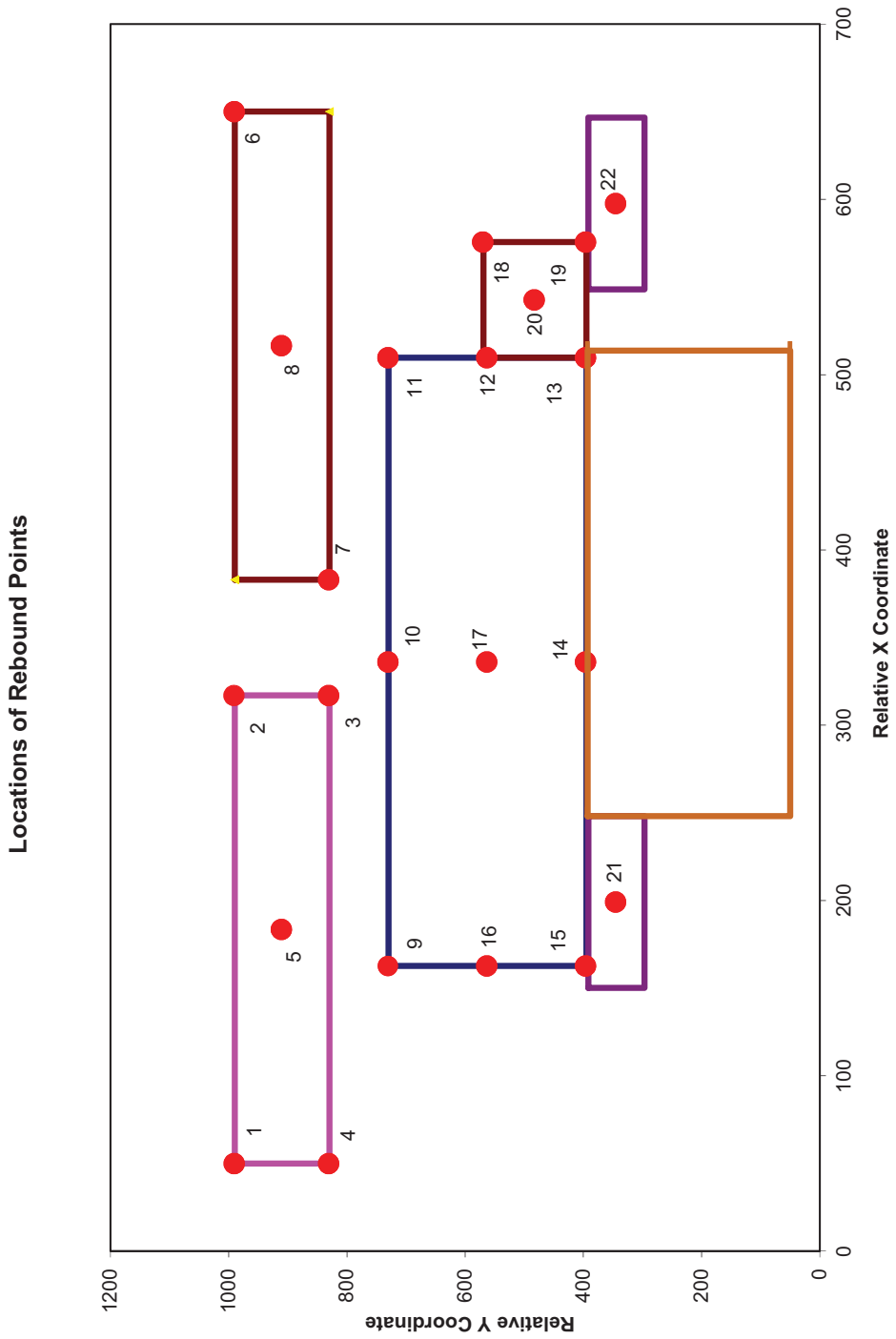
CALCULATION BASED ON UNLOADED AREA 5						CALCULATION BASED ON UNLOADED AREA 6					
Rebound ID	General Coordinates		Local Coordinates		Rebound Component	Rebound ID	General Coordinates		Local Coordinates		Rebound Component
	X	Y	X'	Y'			X	Y	X'	Y'	
1	0.0	940.6	646.4	-547.7	0.000	1	0.0	940.6	-492.7	508.6	0.000
2	267.0	940.6	646.4	-280.7	0.000	2	267.0	940.6	-225.7	508.6	0.000
3	267.0	780.6	486.4	-280.7	0.000	3	267.0	780.6	-225.7	348.6	0.000
4	0.0	780.6	486.4	-547.7	0.000	4	0.0	780.6	-492.7	348.6	0.000
5	133.5	860.6	566.4	-414.2	0.000	5	133.5	860.6	-359.2	428.6	0.000
6	600.1	940.6	646.4	52.4	0.000	6	600.1	940.6	107.4	508.6	0.000
7	333.1	780.6	486.4	-214.6	0.000	7	333.1	780.6	-159.6	348.6	0.000
8	466.6	860.6	566.4	-81.1	0.000	8	466.6	860.6	-26.1	428.6	0.000
9	112.7	680.5	386.3	-435.0	0.000	9	112.7	680.5	-380.0	248.5	0.000
10	286.2	680.5	386.3	-261.5	0.000	10	286.2	680.5	-206.5	248.5	0.000
11	459.7	680.5	386.3	-88.0	0.000	11	459.7	680.5	-33.0	248.5	0.000
12	459.7	513.2	219.0	-88.0	0.000	12	459.7	513.2	-33.0	81.2	0.001
13	459.7	345.9	51.8	-88.0	0.000	13	459.7	345.9	-33.0	-86.0	0.001
14	286.2	345.9	51.8	-261.5	0.000	14	286.2	345.9	-206.5	-86.0	0.000
15	112.7	345.9	51.8	-435.0	0.000	15	112.7	345.9	-380.0	-86.0	0.000
16	112.7	513.2	219.0	-435.0	0.000	16	112.7	513.2	-380.0	81.2	0.000
17	286.2	513.2	219.0	-261.5	0.000	17	286.2	513.2	-206.5	81.2	0.000
18	525.7	520.0	225.8	-22.0	0.000	18	525.7	520.0	33.0	88.0	0.001
19	525.7	345.9	51.8	-22.0	0.001	19	525.7	345.9	33.0	-86.0	0.001
20	492.7	433.0	138.8	-55.0	0.000	20	492.7	433.0	0.0	1.0	0.001
21	149.2	295.2	1.0	-398.5	0.000	21	149.2	295.2	-343.5	-136.8	0.000
22	547.7	295.2	1.0	0.0	0.001	22	547.7	295.2	55.0	-136.8	0.000

CALCULATION BASED ON UNLOADED AREA 7					
Rebound ID	General Coordinates		Local Coordinates		Rebound Component
	X	Y	X'	Y'	
1	0.0	940.6	-330.9	769.3	0.000
2	267.0	940.6	-63.9	769.3	0.000
3	267.0	780.6	-63.9	609.3	0.001
4	0.0	780.6	-330.9	609.3	0.001
5	133.5	860.6	-197.4	689.3	0.001
6	600.1	940.6	269.2	769.3	0.000
7	333.1	780.6	2.2	609.3	0.001
8	466.6	860.6	135.7	689.3	0.001
9	112.7	680.5	-218.3	509.2	0.001
10	286.2	680.5	-44.8	509.2	0.001
11	459.7	680.5	128.8	509.2	0.001
12	459.7	513.2	128.8	341.9	0.001
13	459.7	345.9	128.8	174.6	0.002
14	286.2	345.9	-44.8	174.6	0.003
15	112.7	345.9	-218.3	174.6	0.001
16	112.7	513.2	-218.3	341.9	0.001
17	286.2	513.2	-44.8	341.9	0.001
18	525.7	520.0	194.8	348.7	0.001
19	525.7	345.9	194.8	174.6	0.001
20	492.7	433.0	161.8	261.6	0.001
21	149.2	295.2	-181.8	123.8	0.002
22	547.7	295.2	216.8	123.8	0.002

Appendix B

SUMMARY OF REBOUND							
Rebound Point	X	Y	Rebound Inches	Rebound Point	X	Y	Rebound Inches
1	0.00	940.59	0.04	2	267.00	940.59	0.05
3	267.00	780.59	0.06	4	0.00	780.59	0.05
5	133.50	860.59	0.06	6	600.08	940.59	0.04
7	333.08	780.59	0.06	8	466.58	860.59	0.06
9	112.67	680.50	0.06	10	286.17	680.50	0.07
11	459.67	680.50	0.06	12	459.67	513.21	0.08
13	459.67	345.92	0.08	14	286.17	345.92	0.09
15	112.67	345.92	0.06	16	112.67	513.21	0.07
17	286.17	513.21	0.09	18	525.67	520.00	0.06
19	525.67	345.92	0.07	20	492.67	432.96	0.07
21	149.17	295.17	0.07	22	547.67	295.17	0.06

Appendix B



Rebound Calculation, Non-Layered Method, Best Estimated Modulus, TXU

REBOUND ANALYSIS OF LAYERED SITE-Berm Model, Mathcad Sheet for Cross Check against Excel Sheet

METHODOLOGY

This worksheet has been developed to calculate elastic rebound induced by foundation excavation. The soils below foundations are considered as layered elastic medium and the stress decrement at each layer center due to a rectanglar uniformly unloaded area at or below ground surface is computed by Boussinesq solution. The rebound for each layer is calculated using the vertical stress decrement and elastic modulus of the layer, and total rebound is obtained by summing all layer rebounds in the influenced zone.

Stress Decrement: The equation of Boussinesq solution to compute the stress decrement under the corner of a rectanglar unloaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the unloaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\Delta\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is unload intensity, *m=L/Z, N=B/Z*, and *B, L* and *Z* are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than π/2 when $m^2+n^2+1>m^2n^2$, otherwise between π/2 and π.

Rebound Calculation:The rebound in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^{\,2}}{E_i}$$

where H, E and μ are layer thickness, modulus and poisson ratio, respectively.

Total Rebound: $$S = \sum_1^n S_i$$

where n is number of the total layeres influenced by foundation excavation

DATA INPUT

Number of Unloaded Area: NLA := 7 (Maximum 20)

Number of Stress Points in Z Direction: NSPZ := 25 (Maximum 40)

Number of Rebound Points in Plane: NSPP := 22 (Maximum 40)

Stress Calculation Method: ISCC := 1 (1. Boussinesq)

Unloaded Area:	1	2	3	4	5	6	7
Unloaded Intensity (PSF) of Each Unloaded Area:	5670	5670	5670	5670	5670	5670	5670
Embedment Depth (FT) of Each Unloaded Area:	40	40	40	40	40	40	40

Coordinates (FT) of Corners of Each Unloaded Rectangle:

	X1	Y1	X2	Y2	X3	Y3	X4	Y4
Unloaded Area 1	112.67	679.503	459.67	679.503	459.667	344.92	112.667	344.92
Unloaded Area 2	0	939.587	267	939.587	267	779.587	0	779.5867
Unloaded Area 3	333.08	939.587	600.08	939.587	600.083	779.587	333.083	779.5867
Unloaded Area 4	100.17	341.67	198.17	341.67	198.167	246.67	100.167	246.67
Unloaded Area 5	498.67	341.67	596.67	341.67	596.667	246.67	498.667	246.67
Unloaded Area 6	459.67	519.003	525.67	519.003	525.667	344.92	459.667	344.92
Unloaded Area 7	198.17	342.67	463.67	342.67	463.667	0	198.167	0

Layer	Depth to Layer Center (FT)	Modulus (PSF)	Poisson Ratio
1	3.00	155,547,652	0.3
2	15.00	155,547,652	0.3
3	28.00	44,262,695	0.3
4	36.00	48,648,130	0.3
5	50.00	405,550,066	0.3
6	70.00	405,550,066	0.3
7	92.50	405,550,066	0.3
8	107.00	59,687,742	0.3
9	120.50	313,510,454	0.3
10	149.00	585,032,604	0.3
11	183.00	205,855,826	0.3
12	214.50	72,539,100	0.3
13	239.00	110,220,264	0.3
14	264.00	110,220,264	0.3
15	294.00	110,220,264	0.3
16	324.00	117,958,712	0.3
17	355.00	117,958,712	0.3
18	386.00	110,901,382	0.3
19	417.50	110,901,382	0.3
20	463.00	378,267,514	0.3
21	542.00	378,267,514	0.3
22	642.00	378,267,514	0.3
23	742.00	378,267,514	0.3
24	842.00	378,267,514	0.3
25	942.00	378,267,514	0.3

Coords of Rebound Points (FT)

X	Y
0	940.5867
267	940.5867
267	780.5867
0	780.5867
133.5	860.5867
600.0833	940.5867
333.0833	780.5867
466.5833	860.5867
112.6667	680.5033
286.1667	680.5033
459.6667	680.5033
459.6667	513.2117
459.6667	345.92
286.1667	345.92
112.6667	345.92
112.6667	513.2117
286.1667	513.2117
525.6667	520.0033
525.6667	345.92
492.6667	432.9617
149.1667	295.17
547.6667	295.17

RESULTS:

Stress Decrement Matrix (PSF): The column index is the layer number, and the row index is rebound point number. The total stress decrement contributed by all unloaded areas at each layer center of each rebound point.

Stressinc =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	0	0	0	0	1238	1354	1365	1356	1340	1290	1213	1138	1084	1033	979	933	892	856	825	785	726	660	599	542	490
2	0	0	0	0	1240	1396	1520	1598	1660	1744	1766	1736	1694	1641	1572	1500	1428	1357	1289	1197	1055	905	782	680	594
3	0	0	0	0	1600	1542	1699	1843	1980	2224	2395	2444	2429	2382	2297	2195	2082	1967	1852	1695	1454	1203	1006	849	723
4	0	0	0	0	1597	1476	1445	1432	1419	1391	1353	1315	1286	1256	1222	1187	1153	1118	1084	1034	949	846	750	664	587
5	0	0	0	0	5665	5552	5184	4850	4511	3814	3128	2653	2372	2145	1932	1766	1628	1513	1415	1295	1127	959	825	714	622
6	0	0	0	0	1238	1354	1365	1356	1340	1288	1210	1135	1080	1028	974	928	887	853	822	784	728	664	605	548	496
7	0	0	0	0	1600	1542	1697	1839	1974	2215	2382	2430	2415	2369	2286	2186	2075	1962	1849	1694	1454	1205	1007	850	724
8	0	0	0	0	5665	5551	5182	4847	4506	3805	3114	2635	2353	2126	1914	1750	1615	1504	1408	1292	1128	964	831	720	627
9	0	0	0	0	1239	1382	1488	1571	1653	1814	1946	2005	2015	2001	1962	1905	1836	1761	1681	1566	1376	1164	986	840	720
10	0	0	0	0	2477	2727	2819	2870	2915	2985	3008	2969	2906	2821	2700	2568	2426	2285	2145	1955	1661	1358	1120	934	787
11	0	0	0	0	1239	1384	1497	1588	1680	1865	2027	2108	2132	2127	2093	2038	1967	1887	1801	1675	1465	1230	1035	876	747
12	0	0	0	0	5115	4540	4253	4090	3948	3678	3404	3183	3028	2881	2716	2562	2411	2268	2131	1947	1665	1370	1134	947	799
13	0	0	0	0	4434	4458	4471	4431	4361	4150	3856	3583	3380	3183	2962	2757	2561	2380	2212	1993	1673	1356	1114	927	781
14	0	0	0	0	4930	5389	5451	5423	5366	5171	4851	4512	4240	3966	3651	3356	3076	2821	2588	2291	1875	1483	1197	983	820
15	0	0	0	0	2937	3168	3032	2947	2873	2733	2592	2479	2396	2314	2217	2119	2019	1919	1820	1683	1463	1225	1029	871	742
16	0	0	0	0	2835	2832	2819	2803	2783	2726	2636	2542	2464	2382	2282	2182	2079	1978	1877	1737	1513	1267	1064	899	764
17	0	0	0	0	5669	5655	5595	5524	5435	5183	4808	4435	4149	3870	3559	3276	3012	2775	2558	2282	1888	1509	1225	1008	841
18	0	0	0	0	1240	1401	1544	1641	1727	1871	1976	2020	2028	2018	1988	1943	1885	1819	1747	1638	1449	1230	1041	883	754
19	0	0	0	0	3035	3537	3404	3289	3183	2979	2773	2611	2499	2393	2273	2158	2045	1936	1831	1686	1461	1220	1024	866	738
20	0	0	0	0	5639	5215	4579	4244	3991	3595	3269	3041	2888	2747	2590	2443	2301	2166	2037	1864	1598	1320	1098	921	779
21	0	0	0	0	5650	5305	4620	4221	3918	3466	3128	2908	2765	2633	2485	2346	2208	2078	1952	1782	1524	1257	1046	879	746
22	0	0	0	0	5638	5091	4059	3502	3116	2618	2334	2192	2112	2042	1963	1885	1804	1723	1641	1526	1340	1133	961	819	703

Rebounds Matrix (Inches): The column index of the matrix is the layer number, and the row index is rebound point number. The rebound in this matrix is total rebound contributed by each unloaded area at each layer of each rebound point.

SettleComp =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	0	0	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.005	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.001	0.002	0.002	0.002	0.002	0.001
2	0	0	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.008	0.003	0.005	0.005	0.004	0.004	0.004	0.004	0.002	0.003	0.003	0.002	0.002	0.002
3	0	0	0	0	0.001	0.001	0.001	0.001	0.002	0.001	0.004	0.011	0.005	0.007	0.007	0.006	0.006	0.006	0.006	0.003	0.004	0.003	0.003	0.002	0.002
4	0	0	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.006	0.003	0.004	0.004	0.003	0.003	0.003	0.004	0.002	0.003	0.002	0.002	0.002	0.002
5	0	0	0	0	0.003	0.003	0.003	0.004	0.004	0.002	0.006	0.012	0.005	0.006	0.006	0.005	0.005	0.004	0.005	0.002	0.003	0.003	0.002	0.002	0.002
6	0	0	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.005	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.001	0.002	0.002	0.002	0.002	0.001
7	0	0	0	0	0.001	0.001	0.001	0.001	0.002	0.001	0.004	0.011	0.005	0.007	0.007	0.006	0.006	0.006	0.006	0.003	0.004	0.003	0.003	0.002	0.002
8	0	0	0	0	0.003	0.003	0.003	0.004	0.004	0.002	0.006	0.012	0.005	0.006	0.006	0.005	0.005	0.004	0.005	0.002	0.003	0.003	0.002	0.002	0.002
9	0	0	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.004	0.009	0.004	0.006	0.006	0.005	0.005	0.005	0.005	0.003	0.004	0.003	0.003	0.002	0.002
10	0	0	0	0	0.001	0.001	0.002	0.002	0.002	0.002	0.005	0.013	0.006	0.008	0.008	0.007	0.007	0.007	0.007	0.003	0.005	0.004	0.003	0.003	0.002
11	0	0	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.004	0.009	0.004	0.006	0.006	0.006	0.006	0.006	0.006	0.003	0.004	0.004	0.003	0.003	0.002
12	0	0	0	0	0.003	0.002	0.003	0.003	0.003	0.002	0.006	0.014	0.006	0.009	0.008	0.007	0.007	0.007	0.007	0.003	0.005	0.004	0.003	0.003	0.002
13	0	0	0	0	0.002	0.002	0.003	0.003	0.003	0.003	0.007	0.016	0.007	0.009	0.009	0.008	0.008	0.007	0.007	0.003	0.005	0.004	0.003	0.003	0.002
14	0	0	0	0	0.003	0.003	0.004	0.004	0.004	0.003	0.009	0.02	0.008	0.012	0.011	0.009	0.009	0.008	0.008	0.004	0.005	0.004	0.003	0.003	0.002
15	0	0	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.005	0.011	0.005	0.007	0.007	0.006	0.006	0.006	0.006	0.003	0.004	0.004	0.003	0.003	0.002
16	0	0	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.005	0.011	0.005	0.007	0.007	0.006	0.006	0.006	0.006	0.003	0.004	0.004	0.003	0.003	0.002
17	0	0	0	0	0.003	0.003	0.004	0.004	0.004	0.003	0.009	0.019	0.008	0.012	0.011	0.009	0.009	0.008	0.008	0.004	0.005	0.004	0.004	0.003	0.002
18	0	0	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.004	0.009	0.004	0.006	0.006	0.005	0.006	0.005	0.006	0.003	0.004	0.004	0.003	0.003	0.002
19	0	0	0	0	0.002	0.002	0.002	0.002	0.003	0.002	0.005	0.011	0.005	0.007	0.007	0.006	0.006	0.006	0.006	0.003	0.004	0.004	0.003	0.002	0.002
20	0	0	0	0	0.003	0.003	0.003	0.003	0.003	0.002	0.006	0.013	0.006	0.008	0.008	0.007	0.007	0.006	0.007	0.003	0.005	0.004	0.003	0.003	0.002
21	0	0	0	0	0.003	0.003	0.003	0.003	0.003	0.002	0.006	0.013	0.005	0.008	0.007	0.007	0.007	0.006	0.006	0.003	0.004	0.004	0.003	0.003	0.002
22	0	0	0	0	0.003	0.003	0.003	0.003	0.002	0.002	0.004	0.01	0.004	0.006	0.006	0.005	0.005	0.005	0.005	0.003	0.004	0.003	0.003	0.002	0.002

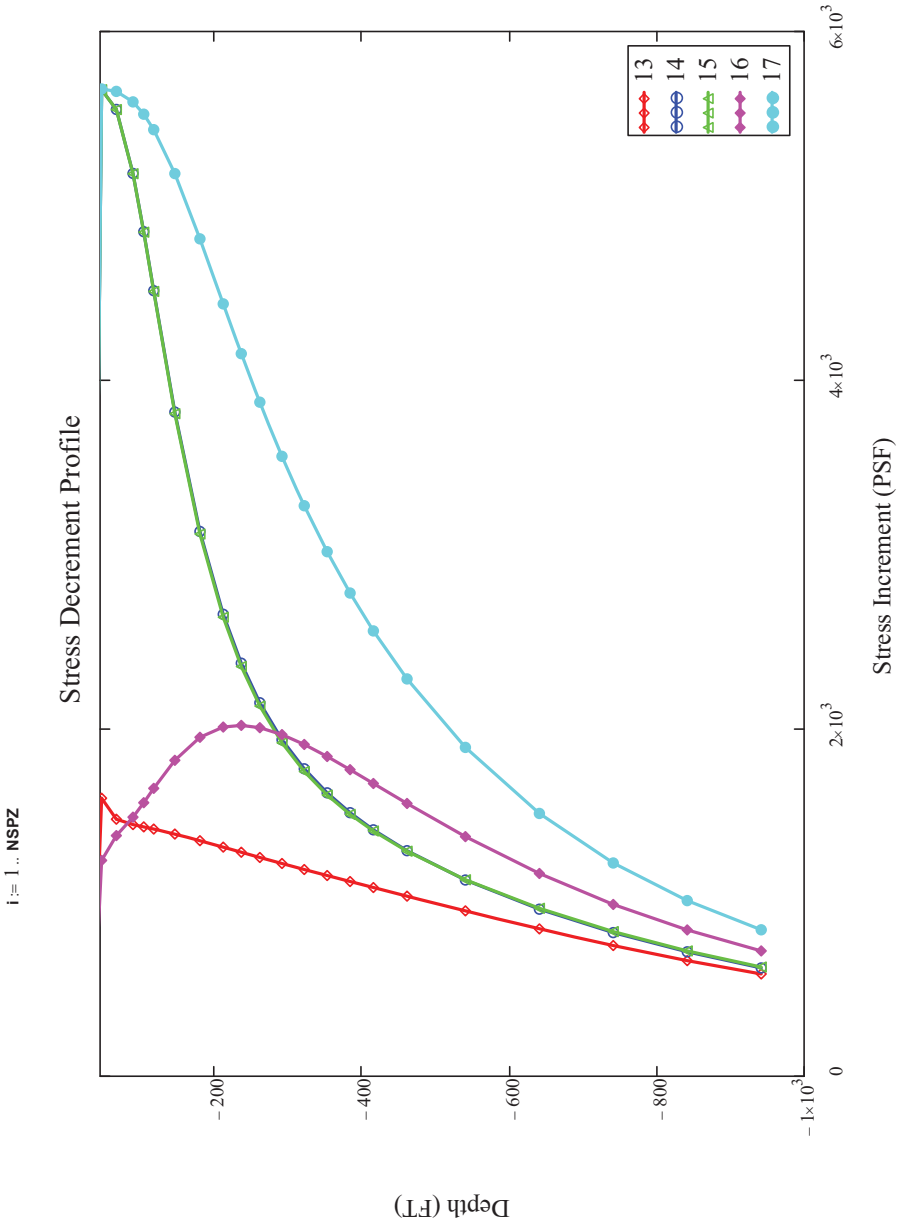
$Settle := TotalSettle(NSPP, NSPZ, SettleComp)$

Total Rebound Matrix (Inches)

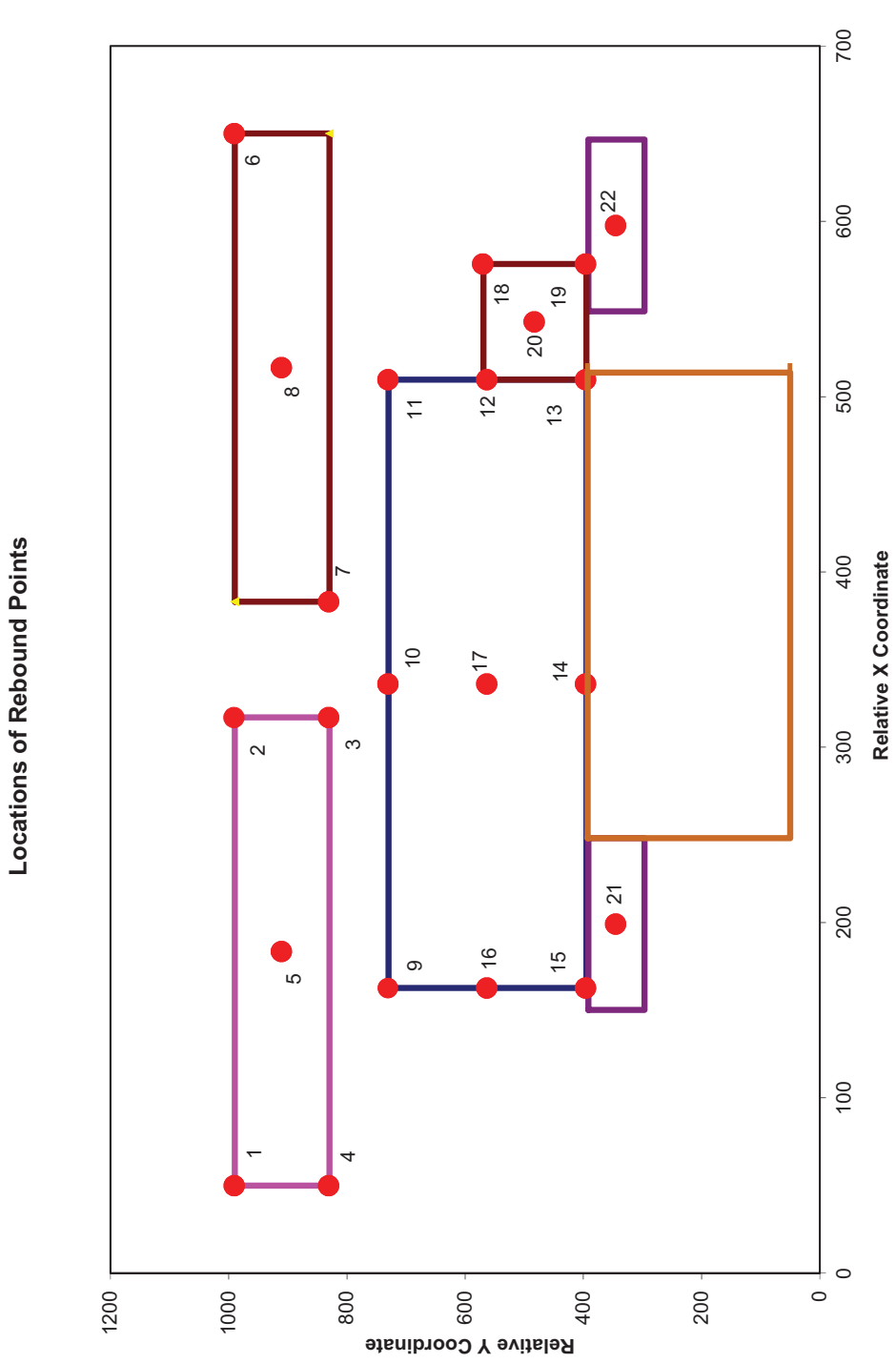
(Column index is the rebound point number)

$Settle^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.04	0.06	0.08	0.05	0.09	0.04	0.08	0.09	0.07	0.1	0.08	0.11	0.11	0.14	0.09	0.09	0.14	0.07	0.09	0.1	0.1	0.08


i := 1 .. NSPZ
Stress Decrement Profile
Depth (FT)
Stress Increment (PSF)
−200
−400
−600
−800
−1×10^3
0
2×10^3
4×10^3
6×10^3
13
14
15
16
17

Appendix B



Rebound Calculation, Layered Method, Best Estimated Modulus, TXU

MODULUS AVERAGING

LAYER ID	LAYER CENTER DEPTH FT	THICKNESS FT	MODULUS PSF	$\sum_{i=1}^{n}\left(E_i \Big/ \sum_{j=1}^{i} h_j\right)$	$\sum_{i=1}^{n}\left(1 \Big/ \sum_{j=1}^{i} h_j\right)$
1.00	3.00	6.00	155,547,652		
2.00	15.00	18.00	155,547,652		
3.00	28.00	8.00	44,262,695		
4.00	36.00	8.00	48,648,130		
5.00	50.00	20.00	405,550,066	20277503	0.050
6.00	70.00	20.00	405,550,066	10138752	0.025
7.00	92.50	25.00	405,550,066	6239232	0.015
8.00	107.00	4.00	59,687,742	865040	0.014
9.00	120.50	23.00	313,510,454	3407722	0.011
10.00	149.00	34.00	585,032,604	4643116	0.008
11.00	183.00	34.00	205,855,826	1286599	0.006
12.00	214.50	29.00	72,539,100	383805	0.005
13.00	239.00	20.00	110,220,264	527370	0.005
14.00	264.00	30.00	110,220,264	461173	0.004
15.00	294.00	30.00	110,220,264	409741	0.004
16.00	324.00	30.00	117,958,712	394511	0.003
17.00	355.00	32.00	117,958,712	356371	0.003
18.00	386.00	30.00	110,901,382	307206	0.003
19.00	417.50	33.00	110,901,382	281476	0.003
20.00	463.00	58.00	378,267,514	836875	0.002
21.00	542.00	100.00	378,267,514	685267	0.002
22.00	642.00	100.00	378,267,514	580165	0.002
23.00	742.00	100.00	378,267,514	503015	0.001
24.00	842.00	100.00	378,267,514	443976	0.001
25.00	942.00	100.00	378,267,514	397340	0.001

$$E_{dw} = \frac{\sum_{i=1}^{n}\left(E_i \Big/ \sum_{j=1}^{i} h_j\right)}{\sum_{i=1}^{n}\left(1 \Big/ \sum_{j=1}^{i} h_j\right)} = \begin{array}{ll} 2199 & \text{KSI} \\ 316701108 & \text{PSF} \end{array}$$

Weighted Modulus Calculation

NON-LAYERED METHOD--BERM MODEL

WORKSHEET OF REBOUND ESTIMATION
Non-layered Method, Berm Model, Mathcad Sheet for Cross Check against Excel Sheet

Reference: Soil Mechanics Principles and Application (1976), William Perloff and William Baron, Page 199-201.

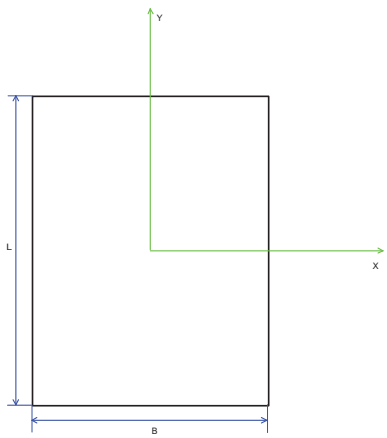


Figure 1. Notation for Rectanglular Loaded Area Shown in Plan View

The vertical rebound of any point of the surface of an elastic half-space uniformly unloaded over a rectangular area is expresses as

$$\delta(x, y, q, B, L) = C(x, y, B, L) \cdot \left[q \cdot B \cdot \frac{(1 - \mu)}{E_d} \right]$$

δ(x,y,q,B,L) = Vertical deformation at point (x,y) induced by a rectangular foundation excavation.

q = unit unload (psf)

B = foundation width (ft)

L = foundation length (ft)

μ= poisson's ratio

E_d = modulus of deformation of the rock foundation

C is a geometric factor which accounts for the shape of the rectangle shown in Figure 1 and the position of the point for which the rebound is being calculated. C can be calculated based on following formulas:

$$A1(x,B) := 1 - 2\cdot\frac{x}{B} \qquad A2(x,B) := 1 + 2\cdot\frac{x}{B}$$

$$B1(y,B,L) := \frac{L}{B} - 2\cdot\frac{y}{B} \qquad B2(y,B,L) := \frac{L}{B} + 2\cdot\frac{y}{B}$$

$$C1(x,y,B,L) := B1(y,B,L)\cdot\ln\left[\frac{\left[\sqrt{(A1(x,B))^2 + (B1(y,B,L))^2} + A1(x,B)\right]}{\left[\sqrt{(A2(x,B))^2 + (B1(y,B,L))^2} - A2(x,B)\right]}\right]$$

$$C2(x,y,B,L) := B2(y,B,L)\cdot\ln\left[\frac{\left[\sqrt{(A1(x,B))^2 + (B2(y,B,L))^2} + A1(x,B)\right]}{\left[\sqrt{(A2(x,B))^2 + (B2(y,B,L))^2} - A2(x,B)\right]}\right]$$

$$C3(x,y,B,L) := A1(x,B)\cdot\ln\left[\frac{\left[\sqrt{(A1(x,B))^2 + (B1(y,B,L))^2} + B1(y,B,L)\right]}{\left[\sqrt{(A1(x,B))^2 + (B2(y,B,L))^2} - B2(y,B,L)\right]}\right]$$

$$C4(x,y,B,L) := A2(x,B)\cdot\ln\left[\frac{\left[\sqrt{(A2(x,B))^2 + (B1(y,B,L))^2} + B1(y,B,L)\right]}{\left[\sqrt{(A2(x,B))^2 + (B2(y,B,L))^2} - B2(y,B,L)\right]}\right]$$

$$C(x,y,B,L) := 0.159\cdot(C1(x,y,B,L) + C2(x,y,B,L) + C3(x,y,B,L) + C4(x,y,B,L))$$

DATA INPUT

Number of Unloaded Area: $NLA := 7$

Number of Rebound Points in Plane: $NSPP := 22$

Elastic Modulus: $E := 316701108$ PSF

Poisson Ratio: $\mu := 0.3$

Unloaded Intensity (PSF) of Each Unloaded Area:

5670	5670	5670	5670	5670	5670	5670

Unloaded Area Coordinates (FT) of Rectangle Corners of Each Unloaded Area:

	X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	112.67	679.5	459.67	679.5	459.67	344.92	112.67	344.92
2	0	939.59	267	939.59	267	779.59	0	779.59
3	333.08	939.59	600.08	939.59	600.08	779.59	333.08	779.59
4	100.17	341.67	198.17	341.67	198.17	246.67	100.17	246.67
5	498.67	341.67	596.67	341.67	596.67	246.67	498.67	246.67
6	459.67	519	525.67	519	525.67	344.92	459.67	344.92
7	198.17	342.67	463.67	342.67	463.67	0	198.17	0

Coordinates of Rebound Points (FT)

X	Y
0	940.59
267	940.59
267	780.59
0	780.59
133.5	860.59
600.08	940.59
333.08	780.59
466.58	860.59
112.67	680.5
286.17	680.5
459.67	680.5
459.67	513.21
459.67	345.92
286.17	345.92
112.67	345.92
112.67	513.21
286.17	513.21
525.67	520
525.67	345.92
492.67	432.96
149.17	295.17
547.67	295.17

$$X := \left| \begin{array}{l} \text{for } i \in 1 .. NSPP \\ \quad X_i \leftarrow CSP_{i,1} \\ X \end{array} \right.$$

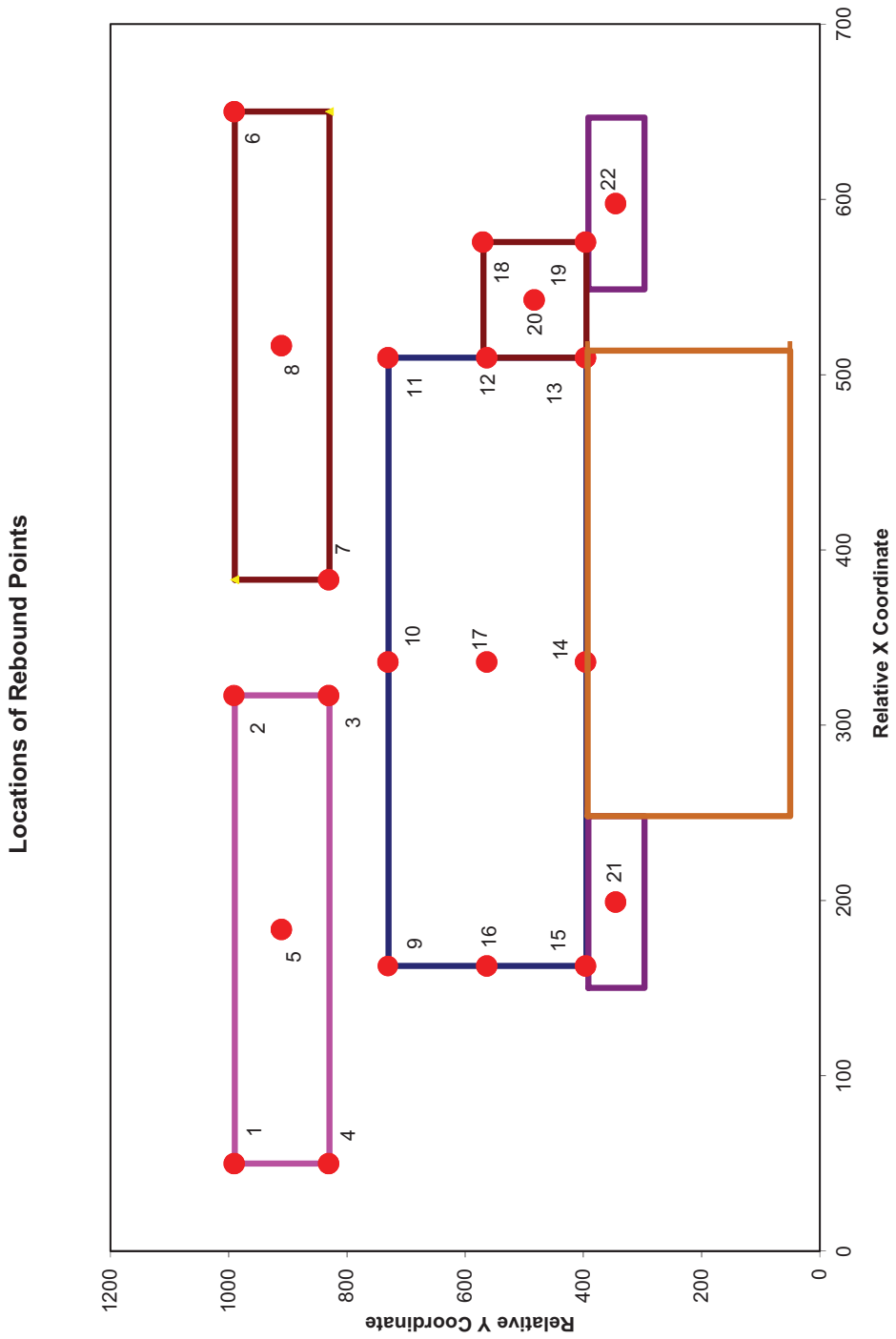
$$Y := \left| \begin{array}{l} \text{for } i \in 1 .. NSPP \\ \quad Y_i \leftarrow CSP_{i,2} \\ Y \end{array} \right.$$

Rebound Matrix (inches): Row index is rebound point number

ST =

	1
1	0.04
2	0.05
3	0.06
4	0.05
5	0.06
6	0.04
7	0.06
8	0.06
9	0.06
10	0.07
11	0.06
12	0.08
13	0.08
14	0.09
15	0.07
16	0.07
17	0.09
18	0.06
19	0.07
20	0.07
21	0.07
22	0.06

Appendix B



Rebound Calculation, Non-Layered Method, Best Estimated Modulus, TXU

APPENDIX C

Bearing Capacity Calculations

BEARING CAPACITY CALCULATION

ASSUMPTION AND BASIS:

1. Reactor Building Complex, R/B Complex.

2. Building will be founded on mat foundation on Unit C

INPUT PARAMETERS:

FOUNDATION WIDTH:	B= 334.58 FEET
FOUNDATION LENGTH:	L= 347 FEET
FOUNDATION EMBEDMENT:	D= 42.25 FEET
ROCK/SOIL EFFECTIVE UNIT WEIGHT:	γ= 88 PCF
ROCK/SOIL COHESION:	c= 73000 PSF
ROCK/SOIL INTERNAL FRICTION ANGLE:	ϕ= 0 DEG
UNCONFINED COMPRESSIVE STRENGTH	q_u= 146000 PSF

REFERENCE:
Corp of Engineers (1994) EM 1110.1-2908

CALCULATION:

METHOD 1: GENERAL SHEAR FAILURE

$$q_{ult} = cN_c C_c + 0.5\gamma B N_\gamma C_\gamma + \gamma D N_q$$

$$N_\phi = \tan^2(45 + \phi/2)$$

$$N_c = 2N_\phi^{1/2}(N_\phi + 1)$$

$$N_\gamma = N_\phi^{1/2}(N_\phi^2 - 1)$$

$$N_q = N_\phi^2$$

INPUT:	B= 334.58 FEET	L= 347 FEET	D= 42.25 FEET	
	γ= 88 PCF	c= 73000 PSF	ϕ= 0	
RESULT:	N_ϕ= 1	N_c= 4	N_γ= 0	N_q= 1
	q_{ult}= 367.3 KSF			

METHOD 2: LOCAL SHEAR FAILURE

$$q_{ult} = cN_c C_c + 0.5\gamma B N_\gamma C_\gamma$$

INPUT:	B= 334.58 FEET	L= 347 FEET	γ= 88 PCF

c= 73000 PSF ϕ= 0

RESULT: N_c= 4 N_γ= 0

q_{ult}= 363.6 KSF

METHOD 3: COMPRESSIVE FAILURE

$$q_{ult} = 2c\tan(45+\phi/2)$$

INPUT: c= 73000 PSF ϕ= 0

RESULT: q_{ult}= 146 KSF

SUMMARY RESULT:

Case 3 Governs: q_{ult}= 146 KSF

BEARING CAPACITY CALCULATION

ASSUMPTION AND BASIS:

1. Turbine Building, T/B.

2. Building will be founded on mat foundation on fill concrete on Unit C.

INPUT PARAMETERS:

FOUNDATION WIDTH:	B= 265.5 FEET
FOUNDATION LENGTH:	L= 342.67 FEET
FOUNDATION EMBEDMENT:	D= 27.17 FEET
ROCK/SOIL EFFECTIVE UNIT WEIGHT:	γ= 88 PCF
ROCK/SOIL COHESION:	c= 73000 PSF
ROCK/SOIL INTERNAL FRICTION ANGLE:	ϕ= 0 DEG
UNCONFINED COMPRESSIVE STRENGTH	q_u= 146000 PSF

REFERENCE:
Corp of Engineers (1994) EM 1110.1-2908

CALCULATION:

METHOD 1: GENERAL SHEAR FAILURE

$$q_{ult} = cN_c C_c + 0.5\gamma B N_\gamma C_\gamma + \gamma D N_q$$

$$N_\phi = \tan^2(45 + \phi/2)$$

$$N_c = 2N_\phi^{1/2}(N_\phi + 1)$$

$$N_\gamma = N_\phi^{1/2}(N_\phi^2 - 1)$$

$$N_q = N_\phi^2$$

INPUT:	B= 265.5 FEET	L= 342.67 FEET	D= 27.17 FEET	
	γ= 88 PCF	c= 73000 PSF	ϕ= 0	
RESULT:	N_ϕ= 1	N_c= 4	N_γ= 0	N_q= 1
	q_{ult}= 356.4 KSF			

METHOD 2: LOCAL SHEAR FAILURE

$$q_{ult} = cN_c C_c + 0.5\gamma B N_\gamma C_\gamma$$

INPUT:	B= 265.5 FEET	L= 342.67 FEET	γ= 88 PCF

c= 73000 PSF ϕ= 0

RESULT: N_c= 4 N_γ= 0

q_{ult}= 354 KSF

METHOD 3: COMPRESSIVE FAILURE

$$q_{ult} = 2c\tan(45+\phi/2)$$

INPUT: c= 73000 PSF ϕ= 0

RESULT: q_{ult}= 146 KSF

SUMMARY RESULT:

Case 3 Governs: q_{ult}= 146 KSF

BEARING CAPACITY CALCULATION

ASSUMPTION AND BASIS:

1. Turbine Generator Pedestal, T/G.

2. Building will be founded on mat foundation on fill concrete on top of Unit C.

INPUT PARAMETERS:

FOUNDATION WIDTH:	B= 62.33 FEET
FOUNDATION LENGTH:	L= 233.42 FEET
FOUNDATION EMBEDMENT:	D= 35.17 FEET
ROCK/SOIL EFFECTIVE UNIT WEIGHT:	γ= 88 PCF
ROCK/SOIL COHESION:	c= 73000 PSF
ROCK/SOIL INTERNAL FRICTION ANGLE:	ϕ= 0 DEG
UNCONFINED COMPRESSIVE STRENGTH	q_u= 146000 PSF

REFERENCE:
Corp of Engineers (1994) EM 1110.1-2908

CALCULATION:

METHOD 1: GENERAL SHEAR FAILURE

$$q_{ult} = cN_c C_c + 0.5\gamma B N_\gamma C_\gamma + \gamma D N_q$$

$$N_\phi = \tan^2(45 + \phi/2)$$

$$N_c = 2N_\phi^{1/2}(N_\phi + 1)$$

$$N_\gamma = N_\phi^{1/2}(N_\phi^2 - 1)$$

$$N_q = N_\phi^2$$

INPUT:	B= 62.33 FEET	L= 233.42 FEET	D= 35.17 FEET	
	γ= 88 PCF	c= 73000 PSF	ϕ= 0	
RESULT:	N_ϕ= 1	N_c= 4	N_γ= 0	N_q= 1
	q_{ult}= 318.2 KSF			

METHOD 2: LOCAL SHEAR FAILURE

$$q_{ult} = cN_c C_c + 0.5\gamma B N_\gamma C_\gamma$$

INPUT:	B= 62.33 FEET	L= 233.42 FEET	γ= 88 PCF

c= 73000 PSF ϕ= 0

RESULT: N_c= 4 N_γ= 0

q_{ult}= 315.2 KSF

METHOD 3: COMPRESSIVE FAILURE

$$q_{ult} = 2c\tan(45 + \phi/2)$$

INPUT: c= 73000 PSF ϕ= 0

RESULT: q_{ult}= 146 KSF

SUMMARY RESULT:

Case 3 Governs: q_{ult}= 146 KSF

BEARING CAPACITY CALCULATION

ASSUMPTION AND BASIS:

1. Power Source Fuel Storage Vault, PSFSV.

2. Building will be founded on mat foundation on Unit C.

INPUT PARAMETERS:

FOUNDATION WIDTH:	B= 95 FEET
FOUNDATION LENGTH:	L= 98 FEET
FOUNDATION EMBEDMENT:	D= 40 FEET
ROCK/SOIL EFFECTIVE UNIT WEIGHT:	γ= 88 PCF
ROCK/SOIL COHESION:	c= 73000 PSF
ROCK/SOIL INTERNAL FRICTION ANGLE:	ϕ= 0 DEG
UNCONFINED COMPRESSIVE STRENGTH	q_u= 146000 PSF

REFERENCE:
Corp of Engineers (1994) EM 1110.1-2908

CALCULATION:

METHOD 1: GENERAL SHEAR FAILURE

$$q_{ult} = cN_c C_c + 0.5\gamma B N_\gamma C_\gamma + \gamma D N_q$$

$$N_\phi = \tan^2(45 + \phi/2)$$

$$N_c = 2N_\phi^{1/2}(N_\phi + 1)$$

$$N_\gamma = N_\phi^{1/2}(N_\phi^2 - 1)$$

$$N_q = N_\phi^2$$

INPUT:	B= 95 FEET	L= 98 FEET	D= 40 FEET	
	γ= 88 PCF	c= 73000 PSF	ϕ= 0	
RESULT:	N_ϕ= 1	N_c= 4	N_γ= 0	N_q= 1
	q_{ult}= 367.3 KSF			

METHOD 2: LOCAL SHEAR FAILURE

$$q_{ult} = cN_c C_c + 0.5\gamma B N_\gamma C_\gamma$$

INPUT:	B= 95 FEET	L= 98 FEET	γ= 88 PCF

c= 73000 PSF ϕ= 0

RESULT: N_c= 4 N_γ= 0

q_{ult}= 363.8 KSF

METHOD 3: COMPRESSIVE FAILURE

$$q_{ult} = 2c\tan(45+\phi/2)$$

INPUT: c= 73000 PSF ϕ= 0

RESULT: q_{ult}= 146 KSF

SUMMARY RESULT:

Case 3 Governs: q_{ult}= 146 KSF

BEARING CAPACITY CALCULATION

ASSUMPTION AND BASIS:

1. Ultimate Heat Sink Related Structures, UHSRS.

2. Building will be founded on mat foundation on fill concrete on Unit C.

INPUT PARAMETERS:

FOUNDATION WIDTH:	B= 160 FEET
FOUNDATION LENGTH:	L= 267 FEET
FOUNDATION EMBEDMENT:	D= 36 FEET
ROCK/SOIL EFFECTIVE UNIT WEIGHT:	γ= 88 PCF
ROCK/SOIL COHESION:	c= 73000 PSF
ROCK/SOIL INTERNAL FRICTION ANGLE:	ϕ= 0 DEG
UNCONFINED COMPRESSIVE STRENGTH	q_u= 146000 PSF

REFERENCE:
Corp of Engineers (1994) EM 1110.1-2908

CALCULATION:

METHOD 1: GENERAL SHEAR FAILURE

$$q_{ult} = cN_cC_c + 0.5\gamma BN_\gamma C_\gamma + \gamma DN_q$$

$$N_\phi = \tan^2(45+\phi/2)$$

$$N_c = 2N_\phi^{1/2}(N_\phi + 1)$$

$$N_\gamma = N_\phi^{1/2}(N_\phi^2 - 1)$$

$$N_q = N_\phi^2$$

INPUT:	B= 160 FEET	L= 267 FEET	D= 36 FEET	
	γ= 88 PCF	c= 73000 PSF	ϕ= 0	
RESULT:	N_ϕ= 1	N_c= 4	N_γ= 0	N_q= 1
	q_{ult}= 342.8 KSF			

METHOD 2: LOCAL SHEAR FAILURE

$$q_{ult} = cN_cC_c + 0.5\gamma BN_\gamma C_\gamma$$

INPUT:	B= 160 FEET	L= 267 FEET	γ= 88 PCF

c= 73000 PSF ϕ= 0

RESULT: N_c= 4 N_γ= 0

q_{ult}= 339.6 KSF

METHOD 3: COMPRESSIVE FAILURE

$$q_{ult} = 2c\tan(45+\phi/2)$$

INPUT: c= 73000 PSF ϕ= 0

RESULT: q_{ult}= 146 KSF

SUMMARY RESULT:

Case 3 Governs: q_{ult}= 146 KSF

APPENDIX D

Liquefaction Calculations

The following provides methodology and a quantitative analysis of the potential for liquefaction of compacted backfill materials. These materials are placed within the excavated areas around the seismic category I and II structures of Units 3 and 4. Duct banks are the only seismic category I structures that are embedded in compacted fill adjacent to the nuclear island.

Two liquefaction analysis methods are considered. The first, herein referred to as the NCEER Method, is based on Youd et al. (2001) and guidelines provided in RG 1.198. This method is considered to be the standard of practice for liquefaction analysis. The second, herein referred to as the EERI Method, is based on Idriss and Boulanger (2008). This method is considered to be the state of the art procedure for liquefaction analysis. Both methods involve semi-empirical field-based procedures and are generally analogous.

The assumptions made, details of the analysis procedures, sample calculations, and figures summarizing the results are presented below.

General References:

Youd, T.L. et al., (2001), Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils, Journal of Geotechnical and Geoenvironmental Engineering, ASCE 127(10), pages 817-833.

Idriss, I.M. and Boulanger, R.W., (2008), Soil Liquefaction during Earthquakes, Earthquake Engineering Research Institute Monograph MNO-12.

Assumptions:

The following is a list of conservative assumptions that were made as part of preparation of this calculation:

- The Peak Ground Acceleration (PGA) is assumed to be 0.1g, based on the results of the ground motion and site response analyses and the US-APWR DCD minimum requirement.
- The Magnitude (M_w) corresponding to this PGA is assumed to be 7.5.
- The permanent groundwater table is well below the foundation or excavation bottoms. However, for the purpose of liquefaction analysis, the groundwater level is assumed to be at the proposed site yard grade (elevation 822 ft).
- A maximum fill thickness of 45 ft is assumed.
- Finished grade in the areas of engineered compacted fill is level.
- The compacted fill is assumed to have a total unit weight of 125 pcf.
- The fines content of the compacted fill is assumed to be less than 5 percent.
- The energy-corrected, overburden-normalized, clean-sand SPT blowcount, $(N_1)_{60,cs}$, as determined in accordance with the References provided herein, of the compacted fill is assumed to be 25 blows/ft.

NCEER Method:

To compare SPT blowcounts at various depths, it is necessary to normalize them to a standard overburden stress (atmospheric pressure). The overburden normalizing factor is determined from the following relationship:

$$C_N = \frac{2.2}{(1.2 + \sigma'_{vo} / P_a)} \leq 1.7$$

Where:

C_N = Overburden normalizing factor

σ'_{vo} = Effective Overburden Stress (kPa)

P_a = Atmospheric Pressure = 101 kPa

Because subsequent semi-empirical equations in the NCEER Method are based on SI units, effective overburden stress is calculated here in terms of kPa.

Earthquake-induced shear stresses are not uniform throughout the soil column. To account for this variation with depth, a stress reduction coefficient is calculated using the following relationships:

$$r_d = 1.0 - 0.00765z \qquad \text{for } z \leq 9.15m$$

$$r_d = 1.174 - 0.0267z \qquad \text{for } 9.15m < z \leq 23m$$

Where:

r_d = Stress Reduction Coefficient

z = Depth (m)

The relationship for the shear stress reduction coefficient is derived in terms of depth in meters.

The earthquake-induced shear stresses on the soil, or cyclic stress ratio (CSR), is then calculated using the following relationship:

$$CSR = 0.65(a_{\max} / g)(\sigma_{vo} / \sigma'_{vo})r_d$$

Where:

CSR = Cyclic Stress Ratio

$a_{\max}$ = Peak Horizontal Acceleration at the ground surface (g), taken as the PGA

g = Acceleration of Gravity

σ_{vo} = Total Overburden Stress (kPa)

σ'_{vo} = Effective Overburden Stress (kPa)

The ability of the soil to resist earthquake-induced shear stresses, or cyclic resistance ratio (CRR) can be expressed as a function of the penetration resistance and is determined from:

$$CRR_{7.5} = \frac{1}{34 - (N_1)_{60}} + \frac{(N_1)_{60}}{135} + \frac{50}{[10 \cdot (N_1)_{60} + 45]^2} - \frac{1}{200}$$

Where:

$CRR_{7.5}$ = Cyclic Resistance Ratio for magnitude 7.5 earthquakes

$(N_1)_{60}$ = Energy-Corrected, Overburden-Normalized, Clean-Sand SPT Blowcount (blows/ft), equal to $(N_1)_{60,cs}$ for this calculation

The nonlinear relationship between CRR and effective overburden stress is accounted for by estimating an overburden correction factor as follows:

$$K_\sigma = (\sigma'_{vo} / P_a)^{(f-1)}$$

Where:

K_σ = Overburden Correction Factor

f = Exponent to express site conditions, taken as 0.7

Finally, the factor of safety against liquefaction is determined by comparing the ratio of CRR to CSR, and applying appropriate correction factors, as shown in the following relationship:

$$FS = (CRR_{7.5} / CSR) \cdot MSF \cdot K_\sigma \cdot K_\alpha$$

Where:

FS = Factor of Safety against Liquefaction

MSF = Magnitude Scaling Factor, equal to 1.0 for M_w = 7.5

K_α = Static Shear Stress Correction Factor, equal to 1.0 for level ground

Liquefaction calculations are performed at 5-foot depth intervals using the NCEER Method and the results are summarized in Table 1. As shown in Table 1, the estimated results for Factor of Safety against liquefaction for saturated compacted fill with a corrected SPT blowcount value of 25 and a PGA of 0.1g ranges between 2.5 and 4.0.

Table 1: Summary of Liquefaction Analysis – NCEER Method
(Factor of Safety against Liquefaction)

Depth (ft/m)	$(N_1)_{60,cs}$ (blows/ft)	σ_{vo} (psf/kPa)	σ'_{vo} (psf/kPa)	C_N	r_d	PGA (g)	CSR	$CRR_{7.5}$	K_σ	FS
5/1.5	25	625/29.9	313/15.0	1.63	0.99	0.1	0.13	0.29	1.77	**4.0**
10/3.0	25	1250/59.9	626/30.0	1.47	0.98	0.1	0.13	0.29	1.44	**3.3**
15/4.6	25	1875/89.8	939/45.0	1.34	0.97	0.1	0.13	0.29	1.27	**3.0**
20/6.1	25	2500/119.7	1252/59.9	1.23	0.95	0.1	0.12	0.29	1.17	**2.8**
25/7.6	25	3125/149.6	1565/74.9	1.13	0.94	0.1	0.12	0.29	1.09	**2.6**
30/9.1	25	3750/179.6	1878/ 89.9	1.05	0.93	0.1	0.12	0.29	1.04	**2.5**
35/10.7	25	4375/209.5	2191/7104.9	0.98	0.89	0.1	0.12	0.29	0.99	**2.5**
40/12.2	25	5000/239.4	2504/119.9	0.92	0.85	0.1	0.11	0.29	0.95	**2.5**
45/13.7	25	5625/269.3	2817/134.9	0.87	0.81	0.1	0.10	0.29	0.92	**2.6**

For comparison purposes, the above liquefaction analysis is also repeated to estimate the SPT blowcount and PGA values needed to trigger liquefaction (FS=1). Results of these parametric studies are shown in Tables 2 and 3. As shown in Table 2, the estimated maximum SPT blowcount values needed to trigger Liquefaction range between 5.1 and 10.4, which is significantly lower that the expected minimum SPT blowcount value for compacted fill (25). The estimated minimum PGA values needed to trigger liquefaction are shown in Table 3 and range

between 0.25g and 0.40g. These values are significantly higher than the design PGA value of 0.1g for the CPNPP site.

Table 2: Summary of Liquefaction Analysis – NCEER Method
(SPT Blowcount Needed to Trigger Liquefaction)

Depth (ft/m)	PGA (g)	FS (Assumed)	$(N_1)_{60,cs}$ Needed to Trigger Liquefaction (blows/ft)	$(N_1)_{60,cs}$ Compacted Fill (blows/ft)
5/1.5	0.1	1.0	**5.0**	25
10/3.0	0.1	1.0	**7.1**	25
15/4.6	0.1	1.0	**8.3**	25
20/6.1	0.1	1.0	**9.2**	25
25/7.6	0.1	1.0	**9.8**	25
30/9.1	0.1	1.0	**10.4**	25
35/10.7	0.1	1.0	**10.4**	25
40/12.2	0.1	1.0	**10.3**	25
45/13.7	0.1	1.0	**10.1**	25

Table 3: Summary of Liquefaction Analysis – NCEER Method
(PGA Values Needed to Trigger Liquefaction)

Depth (ft/m)	$(N_1)_{60,cs}$ Compacted Fill (blows/ft)	FS (Assumed)	PGA Needed to Trigger Liquefaction (g)	PGA (g)
5/1.5	25	1.0	**0.403**	0.1
10/3.0	25	1.0	**0.331**	0.1
15/4.6	25	1.0	**0.297**	0.1
20/6.1	25	1.0	**0.276**	0.1
25/7.6	25	1.0	**0.261**	0.1
30/9.1	25	1.0	**0.250**	0.1
35/10.7	25	1.0	**0.250**	0.1
40/12.2	25	1.0	**0.252**	0.1
45/13.7	25	1.0	**0.255**	0.1

EERI Method:

The overburden normalizing factor used in the EERI Method is a function of SPT blowcount, and therefore requires iteration. The factor can be calculated using the following:

$$C_N = \left(\frac{P_a}{\sigma'_{vo}}\right)^{0.784-0.0768\sqrt{(N_1)_{60}}} \leq 1.7$$

Where:

C_N = Overburden Normalizing Factor

P_a = Atmospheric Pressure = 101 kPa

σ'_{vo} = Effective Overburden Stress (kPa)

$(N_1)_{60}$ = Energy Corrected, Overburden Normalized SPT Blowcount (blows/ft), equal to $(N_1)_{60,cs}$ for this calculation

The shear stress reduction coefficient in the EERI Method is a function of depth and earthquake magnitude and can be determined from the following relationships:

$$r_d = \exp(\alpha(z) + \beta(z)M) \qquad \text{for } z \le 34m$$

Where:

r_d = Shear Stress Reduction Coefficient

$a(z)$ = $-1.012 - 1.126\sin\left(\frac{z}{11.73} + 5.133\right)$

$\beta(z)$ = $0.106 + 0.118\sin\left(\frac{z}{11.28} + 5.142\right)$

z = Depth (m)

M = Earthquake Magnitude

Cyclic stress ratio in the EERI Method is calculated similarly to the NCEER Method, as seen in the following:

$$CSR_{M,\sigma'_{vo}} = 0.65(a_{\max}/g)(\sigma_{vo}/\sigma'_{vo})r_d$$

Where:

$CSR_{M,\sigma'_{vo}}$ = Cyclic Stress Ratio under a specific magnitude and overburden stress

$a_{\max}$ = Peak Horizontal Acceleration at the ground surface (g), taken as the PGA

g = Acceleration of Gravity

σ_{vo} = Total Overburden Stress (kPa)

Overburden correction factor by the EERI Method is determined using effective overburden stress and SPT blowcount, as shown in following relationship:

$$K_\sigma = 1 - C_\sigma \ln\left(\frac{\sigma'_{vo}}{P_a}\right) \le 1.1$$

Where:

K_σ = Overburden Correction Factor

C_σ = $\frac{1}{18.9 - 2.55\sqrt{(N_1)_{60}}} \le 0.3$

The earthquake-induced CSR is also adjusted to the equivalent CSR for the reference values of M=7.5 and σ'_{vo} =1 atm, according to the following relationship:

$$CSR_{M=7.5,\sigma'_{vo}=1} = CSR_{M,\sigma'_{vo}} \frac{1}{MSF} \frac{1}{K_\sigma}$$

Where:

MSF = Magnitude Scaling Factor, equal to 1.0 for M_w = 7.5

The EERI-Method cyclic resistance ratio can be calculated using the following relationship:

$$CRR_{M=7.5,\sigma'_{vo}=1} = \exp\left(\frac{(N_1)_{60,cs}}{14.1} + \left(\frac{(N_1)_{60,cs}}{126}\right)^2 - \left(\frac{(N_1)_{60,cs}}{23.6}\right)^3 + \left(\frac{(N_1)_{60,cs}}{25.4}\right)^4 - 2.8\right)$$

Where:

$CRR_{M=7.5,\sigma'_{vo}=1}$ = Cyclic Resistance Ratio under magnitude 7.5 earthquake and 1 atmosphere overburden stress

$(N_1)_{60,cs}$ = Energy Corrected, Overburden Normalized SPT Blowcount (blows/ft)

Finally, the factor of safety against liquefaction is determined by comparing the ratio of CRR to CSR as follows:

$$FS = \frac{CRR_{M=7.5,\sigma'_{vo}=1}}{CSR_{M=7.5,\sigma'_{vo}=1}}$$

Where:

FS = Factor of Safety against Liquefaction

Liquefaction calculations using the EERI Method are again performed at 5-foot depth intervals, and the results are summarized in Table 4. As shown in Table 4, the estimated results for Factor of Safety against liquefaction for saturated compacted fill with a corrected SPT blowcount value of 25 and a PGA of 0.1g ranges between 2.4 and 2.6.

Table 4: Summary of Liquefaction Analysis – EERI Method
(Factor of Safety against Liquefaction)

Depth (ft/m)	$(N_1)_{60,cs}$ blows/ft	σ_{vo} (psf/kPa)	σ'_{vo} (psf/kPa)	C_N	r_d	K_σ	CSR $M_{7.5},\sigma'_{vo=1}$	CRR $M_{7.5},\sigma'_{vo=1}$	FS
5/1.5	25	625/29.9	313/15.0	1.70	1.00	1.10	0.12	0.29	2.5
10/3.0	25	1250/59.9	626/30.0	1.63	0.98	1.07	0.12	0.29	2.4
15/4.6	25	1875/89.8	939/45.0	1.38	0.97	1.05	0.12	0.29	2.4
20/6.1	25	2500/119.7	1252/59.9	1.23	0.95	1.03	0.12	0.29	2.4
25/7.6	25	3125/149.6	1565/74.9	1.13	0.93	1.02	0.12	0.29	2.5
30/9.1	25	3750/179.6	1878/89.9	1.05	0.91	1.01	0.12	0.29	2.5
35/10.7	25	4375/209.5	2191/7104.9	0.98	0.89	1.00	0.12	0.29	2.5
40/12.2	25	5000/239.4	2504/119.9	0.93	0.86	0.99	0.11	0.29	2.6
45/13.7	25	5625/269.3	2817/134.9	0.89	0.84	0.98	0.11	0.29	2.6

For comparison purposes, the above liquefaction analysis is also repeated to estimate the SPT blowcount and PGA values needed to trigger liquefaction (FS=1). Results of these parametric

studies using the EERI Method are shown in Tables 5 and 6. As shown in Table 5, the estimated maximum SPT blowcount values needed to trigger liquefaction range between 8.9 and 10.2, which is significantly lower than the expected minimum SPT blowcount value for compacted fill (25). The estimated minimum PGA values needed to trigger liquefaction are shown in Table 6 and range between 0.24g and 0.26g. These values are significantly higher than the design PGA value of 0.1g for the CPNPP site.

Table 5: Summary of Liquefaction Analysis – EERI Method
(SPT Blowcount Needed to Trigger Liquefaction)

Depth (ft/m)	PGA (g)	FS (Assumed)	$(N_1)_{60,cs}$ Needed to Trigger Liquefaction (blows/ft)	$(N_1)_{60,cs}$ Compacted Fill (blows/ft)
5/1.5	0.1	1.0	**9.9**	25
10/3.0	0.1	1.0	**10.2**	25
15/4.6	0.1	1.0	**10.2**	25
20/6.1	0.1	1.0	**10.2**	25
25/7.6	0.1	1.0	**10.0**	25
30/9.1	0.1	1.0	**9.8**	25
35/10.7	0.1	1.0	**9.6**	25
40/12.2	0.1	1.0	**9.3**	25
45/13.7	0.1	1.0	**8.9**	25

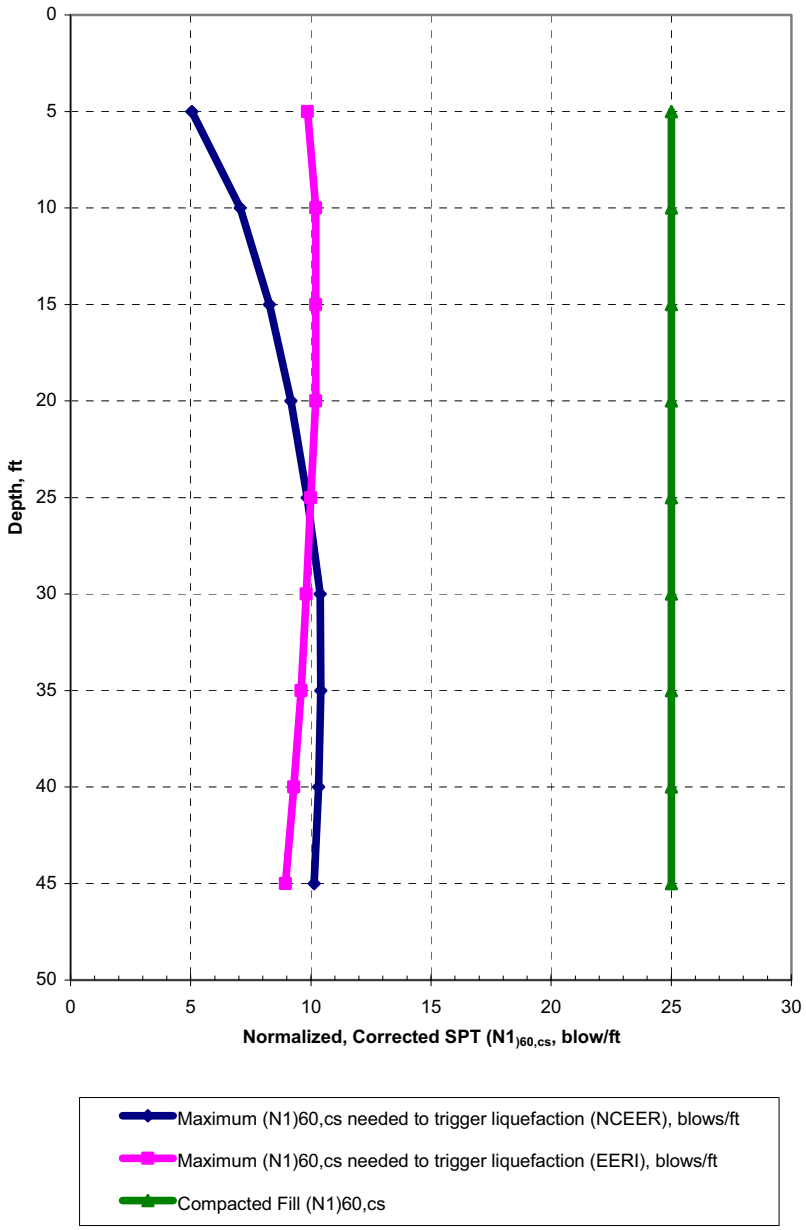
Table 6: Summary of Liquefaction Analysis – EERI Method
(PGA Values Needed to Trigger Liquefaction)

Depth (ft/m)	$(N_1)_{60,cs}$ Compacted Fill (blows/ft)	FS (Assumed)	PGA Needed to Trigger Liquefaction (g)	PGA (g)
5/1.5	25	1.0	**0.248**	0.1
10/3.0	25	1.0	**0.245**	0.1
15/4.6	25	1.0	**0.242**	0.1
20/6.1	25	1.0	**0.243**	0.1
25/7.6	25	1.0	**0.245**	0.1
30/9.1	25	1.0	**0.248**	0.1
35/10.7	25	1.0	**0.251**	0.1
40/12.2	25	1.0	**0.256**	0.1
45/13.7	25	1.0	**0.262**	0.1

The results of both analyses are also presented on Figure D1, Blowcount vs. Depth. This figure demonstrates that for a given depth, the minimum SPT blowcount design criteria for compacted fill is significantly greater than the maximum SPT blowcounts required to trigger liquefaction, as determined by both analysis methods.

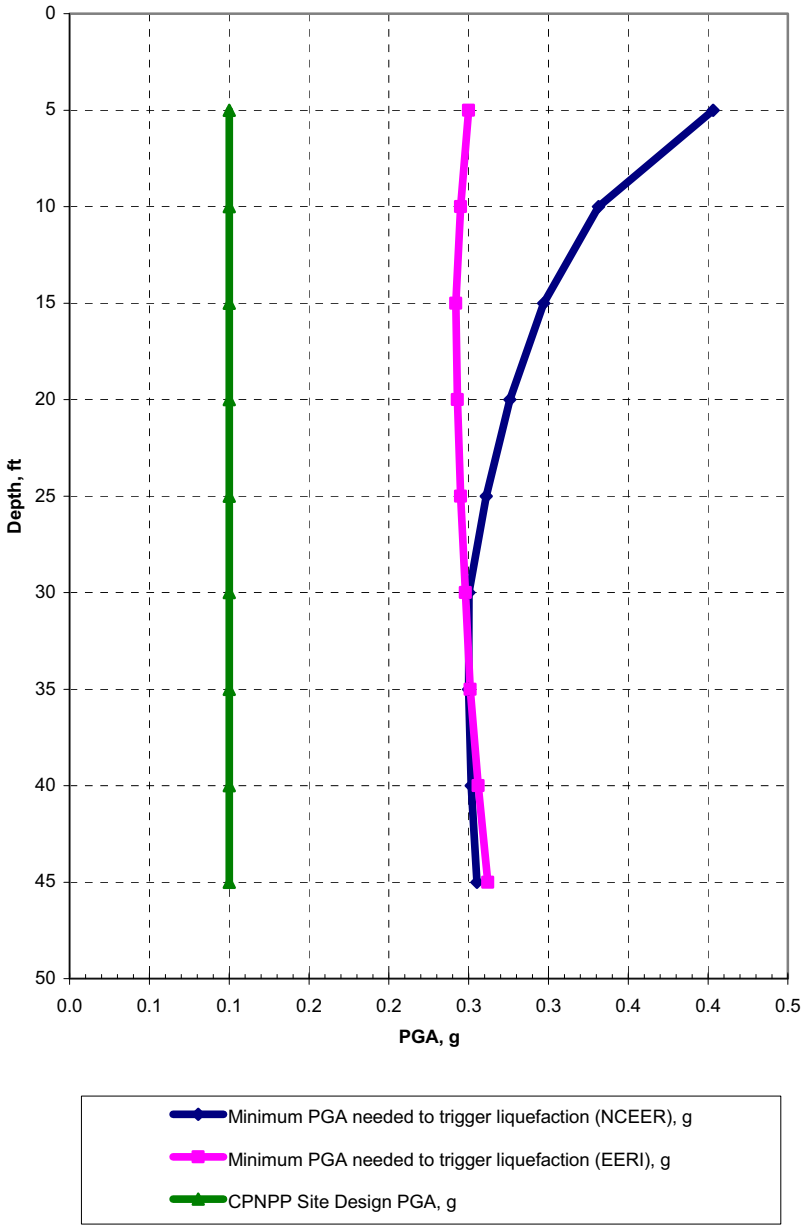
Figure D2, PGA vs. Depth, also shows that the potential for liquefaction is unlikely. The data on Figure D2 are generated by back-calculating the minimum PGA values required to trigger liquefaction in compacted fill with a minimum SPT blowcount value of 25 blows/ft. This figure also demonstrates that for a given depth, the minimum PGA required to trigger liquefaction is significantly greater than the CPNPP site design PGA value of 0.1g.

In summary, the results of liquefaction analyses using the methods described above indicate that liquefaction of the compacted fill is not likely.



Liquefaction Assessment
SPT Blowcount vs. Depth

FIGURE D1



Liquefaction Assessment
PGA vs. Depth

FIGURE D2

APPENDIX E

R/B Complex Settlement Profile Calculations

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, BERM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

SUMMARY OF INPUT

Number of Loaded Areas= 9 **Number of Soil Layers=** 25 **Number of Settlement Points=** 22

Poisson's Ratio= 0.30 **Stress distribution code=** 1 **Depth of Grondwater Table=** 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	171.0	2	-145.6	151.5
3	-145.6	138.0	4	-145.6	105.0
5	-145.6	93.0	6	-145.6	73.5
7	-145.6	54.0	8	-145.6	34.4
9	-145.6	14.9	10	-145.6	0.0
11	-145.6	-24.1	12	-145.6	-43.6
13	-145.6	-63.1	14	-145.6	-82.6
15	-145.6	-102.1	16	-145.6	-110.7
17	-145.6	-141.1	18	-145.6	-160.6
19	-145.6	-174.7	20	-145.6	-199.7
21	-145.6	-219.2	22	-145.6	-238.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
19	417.50	33.00	110901	20	463.00	58.00	378268
21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

Settlement Calculation, Best Estimated Rock Modulus, Line 1 (North Boundary)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Depth (FT)	Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	0.00	0.01	0.03	3.27	6.12	6.50	6.53	6.53	6.54	6.54	6.54	6.54	6.53	6.52	6.33	5.65	4.77	4.76	4.75	4.74	4.65	2.38
70.00	0.10	0.24	0.50	3.27	4.78	5.99	6.34	6.45	6.48	6.50	6.50	6.49	6.45	6.33	5.91	5.60	4.84	4.71	4.65	4.46	3.91	2.35
92.50	0.38	0.73	1.16	3.26	4.18	5.30	5.90	6.18	6.31	6.35	6.37	6.34	6.25	6.04	5.68	5.47	4.84	4.58	4.41	3.97	3.31	2.30
107.00	0.61	1.03	1.49	3.26	3.98	4.96	5.59	5.94	6.13	6.20	6.24	6.20	6.08	5.87	5.54	5.37	4.78	4.46	4.24	3.72	3.09	2.27
120.50	0.82	1.27	1.72	3.24	3.85	4.71	5.32	5.71	5.94	6.03	6.08	6.04	5.91	5.70	5.40	5.25	4.69	4.35	4.10	3.54	2.96	2.26
149.00	1.19	1.65	2.04	3.20	3.65	4.30	4.84	5.23	5.48	5.60	5.68	5.65	5.54	5.35	5.09	4.97	4.46	4.10	3.83	3.27	2.78	2.24
183.00	1.51	1.92	2.24	3.12	3.44	3.94	4.36	4.70	4.94	5.07	5.16	5.15	5.06	4.91	4.69	4.59	4.14	3.81	3.55	3.06	2.65	2.23
214.50	1.68	2.04	2.31	3.00	3.26	3.64	3.99	4.27	4.48	4.59	4.68	4.68	4.61	4.49	4.31	4.22	3.84	3.55	3.32	2.90	2.55	2.20
239.00	1.76	2.08	2.31	2.90	3.11	3.43	3.72	3.96	4.14	4.24	4.33	4.33	4.28	4.17	4.02	3.94	3.60	3.35	3.15	2.77	2.47	2.16
264.00	1.80	2.08	2.28	2.77	2.95	3.22	3.46	3.67	3.82	3.91	3.99	4.00	3.95	3.86	3.73	3.67	3.37	3.15	2.97	2.64	2.38	2.11
294.00	1.80	2.04	2.21	2.62	2.76	2.98	3.18	3.34	3.47	3.55	3.61	3.62	3.59	3.52	3.41	3.35	3.11	2.92	2.77	2.49	2.26	2.04
324.00	1.77	1.97	2.12	2.46	2.58	2.76	2.92	3.05	3.16	3.22	3.28	3.28	3.26	3.20	3.11	3.06	2.86	2.70	2.57	2.34	2.15	1.95
355.00	1.72	1.89	2.01	2.29	2.39	2.54	2.67	2.78	2.87	2.92	2.96	2.97	2.95	2.90	2.83	2.79	2.62	2.48	2.38	2.18	2.02	1.86
386.00	1.65	1.80	1.90	2.13	2.21	2.33	2.44	2.53	2.60	2.64	2.68	2.69	2.67	2.63	2.57	2.54	2.40	2.29	2.20	2.04	1.90	1.76
417.50	1.57	1.70	1.78	1.98	2.04	2.14	2.23	2.30	2.36	2.40	2.43	2.43	2.42	2.39	2.34	2.31	2.19	2.10	2.03	1.89	1.78	1.66
463.00	1.45	1.55	1.62	1.77	1.82	1.90	1.96	2.02	2.06	2.09	2.11	2.12	2.10	2.08	2.04	2.02	1.93	1.86	1.81	1.70	1.61	1.51
542.00	1.25	1.32	1.36	1.46	1.49	1.54	1.58	1.62	1.65	1.66	1.68	1.68	1.67	1.66	1.63	1.62	1.56	1.52	1.48	1.41	1.35	1.29
642.00	1.03	1.07	1.09	1.15	1.17	1.20	1.23	1.25	1.26	1.27	1.28	1.28	1.28	1.27	1.26	1.25	1.21	1.19	1.17	1.12	1.08	1.05
742.00	0.84	0.87	0.89	0.92	0.94	0.95	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.96	0.94	0.93	0.90	0.88	0.85
842.00	0.70	0.72	0.73	0.75	0.76	0.77	0.78	0.79	0.80	0.80	0.80	0.80	0.80	0.80	0.79	0.79	0.78	0.76	0.76	0.74	0.72	0.71
942.00	0.58	0.60	0.60	0.62	0.63	0.63	0.64	0.65	0.65	0.65	0.65	0.66	0.65	0.65	0.65	0.65	0.64	0.63	0.62	0.61	0.60	0.59

Settlement Calculation, Best Estimated Rock Modulus, Line 1 (North Boundary)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
12	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
13	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.06**	**0.07**	**0.08**	**0.10**	**0.11**	**0.12**	**0.12**	**0.13**	**0.13**	**0.14**	**0.14**	**0.14**	**0.14**	**0.13**	**0.13**	**0.13**	**0.12**	**0.11**	**0.11**	**0.10**	**0.09**	**0.08**

Settlement Calculation, Best Estimated Rock Modulus, Line 1 (North Boundary)

Appendix E

Settlement Calculation, Best Estimated Rock Modulus, Line 1 (North Boundary)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-145.6	171.0	**0.06**	**2**	-145.6	151.5	**0.07**
3	-145.6	138.0	**0.08**	**4**	-145.6	105.0	**0.10**
5	-145.6	93.0	**0.11**	**6**	-145.6	73.5	**0.12**
7	-145.6	54.0	**0.12**	**8**	-145.6	34.4	**0.13**
9	-145.6	14.9	**0.13**	**10**	-145.6	0.0	**0.14**
11	-145.6	-24.1	**0.14**	**12**	-145.6	-43.6	**0.14**
13	-145.6	-63.1	**0.14**	**14**	-145.6	-82.6	**0.13**
15	-145.6	-102.1	**0.13**	**16**	-145.6	-110.7	**0.13**
17	-145.6	-141.1	**0.12**	**18**	-145.6	-160.6	**0.11**
19	-145.6	-174.7	**0.11**	**20**	-145.6	-199.7	**0.10**
21	-145.6	-219.2	**0.09**	**22**	-145.6	-238.7	**0.08**

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, BERM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\,\frac{m^2+n^2+2}{m^2+n^2+1} + \sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-100.4	171.0	2	-100.4	151.5
3	-100.4	138.0	4	-100.4	105.0
5	-100.4	93.0	6	-100.4	73.5
7	-100.4	54.0	8	-100.4	34.4
9	-100.4	14.9	10	-100.4	0.0
11	-100.4	-24.1	12	-100.4	-43.6
13	-100.4	-63.1	14	-100.4	-82.6
15	-100.4	-102.1	16	-100.4	-110.7
17	-100.4	-141.1	18	-100.4	-160.6
19	-100.4	-174.7	20	-100.4	-199.7
21	-100.4	-219.2	22	-100.4	-238.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
19	417.50	33.00	110901	20	463.00	58.00	378268
21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

Settlement Calculation, Best Estimated Rock Modulus, Line 2 (45.18' South)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	0.01	0.02	0.06	6.52	12.22	12.98	13.03	13.04	13.05	13.05	13.05	13.05	13.04	13.01	12.53	10.84	8.67	8.64	8.64	8.62	8.46	4.32
70.00	0.17	0.42	0.89	6.28	9.24	11.58	12.22	12.41	12.48	12.50	12.50	12.48	12.40	12.12	11.15	10.40	8.60	8.33	8.22	7.89	6.93	4.15
92.50	0.61	1.19	1.96	5.79	7.47	9.50	10.54	11.02	11.22	11.29	11.32	11.25	11.07	10.66	9.88	9.45	8.13	7.64	7.35	6.64	5.53	3.80
107.00	0.94	1.63	2.40	5.48	6.75	8.44	9.50	10.07	10.36	10.47	10.51	10.43	10.22	9.81	9.16	8.83	7.71	7.16	6.79	5.96	4.94	3.60
120.50	1.23	1.95	2.68	5.23	6.24	7.66	8.66	9.27	9.61	9.75	9.81	9.72	9.51	9.12	8.57	8.29	7.30	6.74	6.33	5.46	4.54	3.44
149.00	1.71	2.40	3.00	4.79	5.47	6.48	7.29	7.86	8.23	8.40	8.50	8.43	8.24	7.93	7.52	7.31	6.50	5.96	5.55	4.73	3.99	3.19
183.00	2.06	2.64	3.10	4.36	4.83	5.53	6.14	6.61	6.94	7.10	7.22	7.18	7.04	6.81	6.50	6.34	5.69	5.21	4.85	4.16	3.58	2.99
214.50	2.21	2.69	3.06	4.01	4.35	4.88	5.34	5.71	5.99	6.14	6.25	6.23	6.13	5.95	5.71	5.58	5.04	4.65	4.34	3.77	3.30	2.83
239.00	2.25	2.67	2.97	3.75	4.03	4.46	4.83	5.14	5.38	5.50	5.61	5.60	5.52	5.38	5.17	5.06	4.61	4.27	4.00	3.51	3.11	2.71
264.00	2.25	2.60	2.86	3.50	3.73	4.07	4.38	4.64	4.84	4.95	5.04	5.04	4.98	4.86	4.68	4.59	4.21	3.92	3.69	3.27	2.93	2.59
294.00	2.19	2.49	2.70	3.22	3.40	3.67	3.92	4.12	4.28	4.37	4.45	4.45	4.40	4.31	4.17	4.10	3.78	3.54	3.36	3.01	2.73	2.44
324.00	2.11	2.36	2.53	2.95	3.10	3.32	3.51	3.68	3.80	3.88	3.94	3.94	3.91	3.83	3.72	3.66	3.40	3.21	3.06	2.77	2.53	2.30
355.00	2.01	2.22	2.36	2.70	2.81	2.99	3.15	3.28	3.38	3.44	3.49	3.50	3.47	3.41	3.32	3.27	3.06	2.90	2.78	2.54	2.34	2.15
386.00	1.90	2.07	2.19	2.47	2.56	2.70	2.83	2.93	3.02	3.06	3.11	3.11	3.09	3.04	2.97	2.93	2.76	2.63	2.53	2.33	2.17	2.00
417.50	1.78	1.93	2.02	2.25	2.33	2.44	2.55	2.63	2.70	2.74	2.77	2.78	2.76	2.72	2.66	2.63	2.49	2.38	2.30	2.14	2.00	1.86
463.00	1.62	1.73	1.81	1.98	2.04	2.12	2.20	2.26	2.31	2.34	2.37	2.37	2.36	2.33	2.28	2.26	2.16	2.08	2.01	1.89	1.78	1.68
542.00	1.36	1.43	1.48	1.59	1.63	1.68	1.73	1.77	1.80	1.82	1.83	1.84	1.83	1.81	1.78	1.77	1.70	1.65	1.61	1.53	1.47	1.40
642.00	1.09	1.14	1.17	1.23	1.25	1.29	1.31	1.34	1.35	1.36	1.37	1.37	1.37	1.36	1.34	1.33	1.30	1.27	1.24	1.20	1.16	1.11
742.00	0.89	0.91	0.93	0.97	0.99	1.01	1.02	1.04	1.05	1.05	1.06	1.06	1.06	1.05	1.04	1.04	1.01	0.99	0.98	0.95	0.92	0.90
842.00	0.73	0.75	0.76	0.78	0.79	0.80	0.81	0.82	0.83	0.83	0.84	0.84	0.84	0.83	0.83	0.82	0.81	0.80	0.79	0.77	0.75	0.73
942.00	0.60	0.62	0.62	0.64	0.65	0.66	0.66	0.67	0.67	0.68	0.68	0.68	0.68	0.67	0.67	0.67	0.66	0.65	0.64	0.63	0.62	0.61

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
13	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.07**	**0.08**	**0.09**	**0.12**	**0.14**	**0.15**	**0.16**	**0.17**	**0.18**	**0.18**	**0.18**	**0.18**	**0.18**	**0.18**	**0.17**	**0.16**	**0.15**	**0.14**	**0.13**	**0.12**	**0.11**	**0.09**

Settlement Calculation, Best Estimated Rock Modulus, Line 2 (45.18' South)

Settlement Calculation, Best Estimated Rock Modulus, Line 2 (45.18' South)

SUMMARY OF SETTLEMENT							
Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-100.4	171.0	0.07	2	-100.4	151.5	0.08
3	-100.4	138.0	0.09	4	-100.4	105.0	0.12
5	-100.4	93.0	0.14	6	-100.4	73.5	0.15
7	-100.4	54.0	0.16	8	-100.4	34.4	0.17
9	-100.4	14.9	0.18	10	-100.4	0.0	0.18
11	-100.4	-24.1	0.18	12	-100.4	-43.6	0.18
13	-100.4	-63.1	0.18	14	-100.4	-82.6	0.18
15	-100.4	-102.1	0.17	16	-100.4	-110.7	0.16
17	-100.4	-141.1	0.15	18	-100.4	-160.6	0.14
19	-100.4	-174.7	0.13	20	-100.4	-199.7	0.12
21	-100.4	-219.2	0.11	22	-100.4	-238.7	0.09

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, BERM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Best Estimated Rock Modulus, Line 3 (145.58' South)

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	0.0	171.0	2	0.0	151.5
3	0.0	138.0	4	0.0	105.0
5	0.0	93.0	6	0.0	73.5
7	0.0	54.0	8	0.0	34.4
9	0.0	14.9	10	0.0	0.0
11	0.0	-24.1	12	0.0	-43.6
13	0.0	-63.1	14	0.0	-82.6
15	0.0	-102.1	16	0.0	-110.7
17	0.0	-141.1	18	0.0	-160.6
19	0.0	-174.7	20	0.0	-199.7
21	0.0	-219.2	22	0.0	-238.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
19	417.50	33.00	110901	20	463.00	58.00	378268
21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

Settlement Calculation, Best Estimated Rock Modulus, Line 3 (145.58' South)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	0.17	0.32	0.38	6.70	12.30	13.01	13.06	13.07	13.07	13.07	13.07	13.07	13.07	13.03	12.46	10.44	7.84	7.81	7.80	7.78	7.63	3.90
70.00	1.01	1.75	2.34	7.33	10.02	12.14	12.72	12.89	12.95	12.97	12.97	12.94	12.84	12.49	11.30	10.39	8.20	7.86	7.74	7.39	6.47	3.90
92.50	1.75	2.78	3.72	7.46	9.02	10.89	11.87	12.32	12.52	12.58	12.59	12.49	12.25	11.71	10.72	10.17	8.50	7.88	7.53	6.74	5.61	3.89
107.00	2.15	3.23	4.19	7.36	8.59	10.20	11.23	11.79	12.07	12.17	12.19	12.06	11.77	11.22	10.37	9.94	8.48	7.78	7.33	6.38	5.28	3.88
120.50	2.45	3.53	4.45	7.19	8.21	9.63	10.62	11.23	11.57	11.70	11.73	11.59	11.29	10.76	10.02	9.65	8.35	7.62	7.11	6.09	5.06	3.86
149.00	2.89	3.86	4.62	6.70	7.45	8.53	9.38	9.99	10.37	10.54	10.60	10.47	10.19	9.76	9.19	8.90	7.83	7.12	6.60	5.59	4.71	3.78
183.00	3.11	3.90	4.50	6.03	6.57	7.37	8.04	8.56	8.91	9.08	9.16	9.08	8.87	8.53	8.10	7.88	7.01	6.40	5.94	5.06	4.34	3.62
214.50	3.12	3.76	4.23	5.40	5.81	6.43	6.96	7.38	7.68	7.83	7.92	7.87	7.71	7.45	7.11	6.94	6.24	5.72	5.33	4.60	4.02	3.44
239.00	3.05	3.59	3.98	4.94	5.28	5.78	6.22	6.57	6.83	6.96	7.05	7.01	6.89	6.68	6.40	6.26	5.66	5.23	4.89	4.27	3.77	3.27
264.00	2.94	3.40	3.72	4.51	4.78	5.19	5.55	5.84	6.06	6.18	6.26	6.24	6.14	5.97	5.74	5.62	5.12	4.75	4.47	3.94	3.52	3.10
294.00	2.78	3.15	3.41	4.03	4.25	4.57	4.86	5.09	5.27	5.36	5.44	5.42	5.35	5.22	5.04	4.94	4.54	4.24	4.01	3.58	3.23	2.89
324.00	2.60	2.90	3.11	3.61	3.79	4.04	4.27	4.46	4.60	4.68	4.74	4.73	4.68	4.57	4.43	4.35	4.03	3.79	3.60	3.25	2.96	2.68
355.00	2.41	2.66	2.83	3.23	3.37	3.57	3.75	3.90	4.02	4.08	4.13	4.13	4.09	4.01	3.89	3.83	3.57	3.38	3.23	2.94	2.71	2.47
386.00	2.23	2.44	2.57	2.90	3.01	3.17	3.32	3.44	3.53	3.58	3.62	3.62	3.59	3.52	3.43	3.39	3.18	3.02	2.90	2.67	2.47	2.28
417.50	2.06	2.23	2.34	2.60	2.69	2.82	2.94	3.03	3.11	3.15	3.18	3.18	3.16	3.11	3.04	3.00	2.83	2.71	2.61	2.42	2.26	2.10
463.00	1.83	1.96	2.04	2.24	2.31	2.40	2.49	2.56	2.61	2.64	2.67	2.67	2.65	2.62	2.56	2.54	2.41	2.32	2.25	2.10	1.98	1.86
542.00	1.50	1.58	1.63	1.76	1.80	1.86	1.91	1.95	1.98	2.00	2.02	2.02	2.01	1.99	1.96	1.94	1.86	1.81	1.76	1.67	1.60	1.52
642.00	1.18	1.22	1.26	1.33	1.35	1.38	1.41	1.44	1.46	1.47	1.47	1.48	1.47	1.46	1.44	1.43	1.39	1.36	1.33	1.28	1.23	1.19
742.00	0.94	0.97	0.99	1.03	1.04	1.06	1.08	1.10	1.11	1.11	1.12	1.12	1.12	1.11	1.10	1.09	1.07	1.05	1.03	1.00	0.97	0.94
842.00	0.76	0.78	0.79	0.82	0.83	0.84	0.85	0.86	0.87	0.87	0.88	0.88	0.87	0.87	0.86	0.86	0.84	0.83	0.82	0.80	0.78	0.76
942.00	0.63	0.64	0.65	0.67	0.67	0.68	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.69	0.68	0.67	0.67	0.65	0.64	0.63

Settlement Calculation, Best Estimated Rock Modulus, Line 3 (145.58' South)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
8	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
9	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.09**	**0.11**	**0.12**	**0.15**	**0.17**	**0.18**	**0.20**	**0.21**	**0.21**	**0.21**	**0.22**	**0.22**	**0.21**	**0.21**	**0.20**	**0.19**	**0.17**	**0.16**	**0.15**	**0.14**	**0.12**	**0.11**

Settlement Calculation, Best Estimated Rock Modulus, Line 3 (145.58' South)

SUMMARY OF SETTLEMENT							
Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	0.0	171.0	0.09	2	0.0	151.5	0.11
3	0.0	138.0	0.12	4	0.0	105.0	0.15
5	0.0	93.0	0.17	6	0.0	73.5	0.18
7	0.0	54.0	0.20	8	0.0	34.4	0.21
9	0.0	14.9	0.21	10	0.0	0.0	0.21
11	0.0	-24.1	0.22	12	0.0	-43.6	0.22
13	0.0	-63.1	0.21	14	0.0	-82.6	0.21
15	0.0	-102.1	0.20	16	0.0	-110.7	0.19
17	0.0	-141.1	0.17	18	0.0	-160.6	0.16
19	0.0	-174.7	0.15	20	0.0	-199.7	0.14
21	0.0	-219.2	0.12	22	0.0	-238.7	0.11

Settlement Calculation, Best Estimated Rock Modulus, Line 3 (145.58' South)

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, BERM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Best Estimated Rock Modulus, Line 4 (159.747' South)

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES

ID	X	Y	ID	X	Y
1	14.2	171.0	2	14.2	151.5
3	14.2	138.0	4	14.2	105.0
5	14.2	93.0	6	14.2	73.5
7	14.2	54.0	8	14.2	34.4
9	14.2	14.9	10	14.2	0.0
11	14.2	-24.1	12	14.2	-43.6
13	14.2	-63.1	14	14.2	-82.6
15	14.2	-102.1	16	14.2	-110.7
17	14.2	-141.1	18	14.2	-160.6
19	14.2	-174.7	20	14.2	-199.7
21	14.2	-219.2	22	14.2	-238.7

LAYER COMPRESSIBILITY

LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
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21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

Settlement Calculation, Best Estimated Rock Modulus, Line 4 (159.747' South)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Depth (FT)	Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	1.84	3.60	3.69	8.36	12.47	13.02	13.06	13.07	13.07	13.07	13.07	13.07	13.07	13.03	12.46	10.44	7.83	7.81	7.80	7.78	7.63	3.90
70.00	1.96	3.37	4.08	8.28	10.48	12.24	12.74	12.90	12.95	12.97	12.97	12.93	12.83	12.48	11.29	10.38	8.19	7.86	7.73	7.39	6.47	3.90
92.50	2.31	3.58	4.58	8.01	9.39	11.05	11.92	12.33	12.52	12.58	12.58	12.48	12.23	11.69	10.70	10.16	8.48	7.86	7.51	6.73	5.60	3.88
107.00	2.56	3.78	4.77	7.76	8.88	10.36	11.29	11.81	12.07	12.16	12.17	12.04	11.75	11.20	10.35	9.92	8.46	7.76	7.31	6.36	5.27	3.86
120.50	2.77	3.93	4.87	7.50	8.45	9.76	10.69	11.26	11.57	11.69	11.71	11.57	11.26	10.74	10.00	9.63	8.32	7.59	7.09	6.07	5.04	3.84
149.00	3.09	4.09	4.86	6.89	7.60	8.64	9.45	10.02	10.38	10.53	10.58	10.45	10.17	9.73	9.16	8.88	7.80	7.09	6.57	5.56	4.68	3.76
183.00	3.23	4.03	4.63	6.14	6.67	7.45	8.10	8.59	8.93	9.09	9.16	9.07	8.85	8.52	8.08	7.86	6.99	6.38	5.92	5.04	4.33	3.61
214.50	3.20	3.84	4.31	5.47	5.88	6.48	7.00	7.41	7.70	7.84	7.92	7.87	7.70	7.45	7.10	6.93	6.22	5.71	5.32	4.59	4.01	3.43
239.00	3.11	3.65	4.04	5.00	5.33	5.82	6.25	6.60	6.85	6.97	7.06	7.02	6.89	6.68	6.40	6.25	5.65	5.22	4.88	4.26	3.76	3.27
264.00	2.98	3.44	3.76	4.55	4.82	5.23	5.58	5.87	6.08	6.19	6.27	6.24	6.14	5.97	5.74	5.62	5.12	4.75	4.47	3.94	3.51	3.10
294.00	2.81	3.18	3.44	4.06	4.28	4.60	4.88	5.11	5.29	5.38	5.45	5.43	5.36	5.22	5.04	4.94	4.54	4.24	4.01	3.58	3.23	2.89
324.00	2.62	2.92	3.14	3.64	3.81	4.06	4.29	4.47	4.61	4.69	4.75	4.74	4.68	4.58	4.43	4.36	4.03	3.79	3.60	3.25	2.96	2.68
355.00	2.43	2.68	2.85	3.25	3.39	3.59	3.77	3.92	4.03	4.09	4.14	4.13	4.09	4.01	3.90	3.84	3.58	3.38	3.23	2.94	2.71	2.47
386.00	2.25	2.45	2.59	2.91	3.02	3.18	3.33	3.45	3.54	3.59	3.63	3.63	3.59	3.53	3.44	3.39	3.18	3.02	2.90	2.67	2.48	2.28
417.50	2.07	2.24	2.35	2.61	2.70	2.83	2.95	3.04	3.12	3.16	3.19	3.19	3.16	3.11	3.04	3.00	2.84	2.71	2.61	2.42	2.26	2.10
463.00	1.84	1.97	2.05	2.25	2.31	2.41	2.50	2.57	2.62	2.65	2.67	2.67	2.66	2.62	2.57	2.54	2.42	2.32	2.25	2.10	1.98	1.86
542.00	1.50	1.58	1.64	1.76	1.80	1.86	1.91	1.95	1.99	2.00	2.02	2.02	2.01	1.99	1.96	1.94	1.87	1.81	1.76	1.67	1.60	1.52
642.00	1.18	1.23	1.26	1.33	1.35	1.39	1.41	1.44	1.46	1.47	1.48	1.48	1.47	1.46	1.44	1.43	1.39	1.36	1.33	1.28	1.23	1.19
742.00	0.94	0.97	0.99	1.03	1.05	1.07	1.08	1.10	1.11	1.11	1.12	1.12	1.12	1.11	1.10	1.09	1.07	1.05	1.03	1.00	0.97	0.95
842.00	0.76	0.78	0.79	0.82	0.83	0.84	0.85	0.86	0.87	0.87	0.88	0.88	0.87	0.87	0.86	0.86	0.84	0.83	0.82	0.80	0.78	0.77
942.00	0.63	0.64	0.65	0.67	0.67	0.68	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.69	0.68	0.67	0.67	0.65	0.64	0.63

Settlement Calculation, Best Estimated Rock Modulus, Line 4 (159.747' South)

Appendix E

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
8	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
9	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.10**	**0.11**	**0.13**	**0.16**	**0.17**	**0.19**	**0.20**	**0.21**	**0.21**	**0.21**	**0.22**	**0.22**	**0.21**	**0.21**	**0.20**	**0.19**	**0.17**	**0.16**	**0.15**	**0.14**	**0.12**	**0.11**

Settlement Calculation, Best Estimated Rock Modulus, Line 4 (159.747' South)

Appendix E

Settlement Calculation, Best Estimated Rock Modulus, Line 4 (159.747' South)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	14.2	171.0	**0.10**	**2**	14.2	151.5	**0.11**
3	14.2	138.0	**0.13**	**4**	14.2	105.0	**0.16**
5	14.2	93.0	**0.17**	**6**	14.2	73.5	**0.19**
7	14.2	54.0	**0.20**	**8**	14.2	34.4	**0.21**
9	14.2	14.9	**0.21**	**10**	14.2	0.0	**0.21**
11	14.2	-24.1	**0.22**	**12**	14.2	-43.6	**0.22**
13	14.2	-63.1	**0.21**	**14**	14.2	-82.6	**0.21**
15	14.2	-102.1	**0.20**	**16**	14.2	-110.7	**0.19**
17	14.2	-141.1	**0.17**	**18**	14.2	-160.6	**0.16**
19	14.2	-174.7	**0.15**	**20**	14.2	-199.7	**0.14**
21	14.2	-219.2	**0.12**	**22**	14.2	-238.7	**0.11**

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, BERM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Best Estimated Rock Modulus, Line 5 (251.58' South)

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	106.0	171.0	2	106.0	151.5
3	106.0	138.0	4	106.0	105.0
5	106.0	93.0	6	106.0	73.5
7	106.0	54.0	8	106.0	34.4
9	106.0	14.9	10	106.0	0.0
11	106.0	-24.1	12	106.0	-43.6
13	106.0	-63.1	14	106.0	-82.6
15	106.0	-102.1	16	106.0	-110.7
17	106.0	-141.1	18	106.0	-160.6
19	106.0	-174.7	20	106.0	-199.7
21	106.0	-219.2	22	106.0	-238.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
19	417.50	33.00	110901	20	463.00	58.00	378268
21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

Settlement Calculation, Best Estimated Rock Modulus, Line 5 (251.58' South)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	3.66	7.16	7.30	9.30	11.04	11.28	11.30	11.30	11.30	11.30	11.30	11.30	11.29	11.26	10.75	8.94	6.61	6.58	6.58	6.56	6.44	3.29
70.00	3.66	6.14	6.98	9.10	10.05	10.82	11.05	11.12	11.14	11.15	11.14	11.11	11.02	10.72	9.66	8.85	6.91	6.62	6.51	6.23	5.45	3.28
92.50	3.65	5.40	6.40	8.49	9.17	9.95	10.36	10.56	10.65	10.67	10.65	10.57	10.35	9.89	9.03	8.56	7.10	6.58	6.28	5.63	4.68	3.24
107.00	3.62	5.09	6.02	7.99	8.59	9.34	9.81	10.07	10.19	10.23	10.21	10.09	9.84	9.37	8.64	8.27	7.03	6.44	6.07	5.28	4.38	3.21
120.50	3.58	4.84	5.68	7.51	8.06	8.77	9.26	9.56	9.72	9.77	9.75	9.61	9.35	8.90	8.28	7.96	6.87	6.26	5.85	5.01	4.16	3.16
149.00	3.45	4.40	5.06	6.56	7.02	7.66	8.14	8.47	8.67	8.74	8.73	8.60	8.35	7.98	7.50	7.27	6.38	5.80	5.37	4.55	3.83	3.07
183.00	3.26	3.97	4.47	5.63	6.00	6.53	6.96	7.27	7.48	7.56	7.57	7.47	7.28	6.99	6.62	6.44	5.73	5.22	4.84	4.13	3.55	2.96
214.50	3.07	3.63	4.02	4.93	5.24	5.67	6.04	6.31	6.50	6.59	6.62	6.55	6.39	6.17	5.88	5.73	5.15	4.72	4.40	3.80	3.32	2.85
239.00	2.93	3.39	3.72	4.48	4.74	5.11	5.42	5.67	5.84	5.92	5.96	5.90	5.78	5.60	5.35	5.23	4.73	4.36	4.09	3.57	3.16	2.75
264.00	2.78	3.17	3.44	4.08	4.29	4.61	4.88	5.09	5.24	5.31	5.35	5.32	5.22	5.07	4.86	4.76	4.34	4.02	3.78	3.34	2.99	2.64
294.00	2.60	2.92	3.14	3.66	3.83	4.09	4.31	4.49	4.61	4.68	4.72	4.69	4.62	4.50	4.34	4.25	3.91	3.65	3.45	3.08	2.79	2.50
324.00	2.42	2.69	2.87	3.29	3.43	3.64	3.82	3.97	4.08	4.13	4.17	4.16	4.10	4.00	3.87	3.80	3.52	3.31	3.15	2.84	2.60	2.35
355.00	2.25	2.47	2.62	2.96	3.08	3.25	3.40	3.52	3.61	3.65	3.69	3.67	3.63	3.56	3.45	3.40	3.17	3.00	2.86	2.61	2.41	2.20
386.00	2.09	2.27	2.39	2.67	2.77	2.91	3.03	3.13	3.20	3.24	3.27	3.26	3.23	3.17	3.08	3.04	2.85	2.71	2.60	2.40	2.23	2.05
417.50	1.93	2.08	2.18	2.41	2.49	2.61	2.71	2.79	2.85	2.88	2.90	2.90	2.87	2.83	2.76	2.72	2.57	2.46	2.37	2.20	2.06	1.91
463.00	1.73	1.84	1.92	2.10	2.16	2.24	2.32	2.38	2.42	2.45	2.47	2.47	2.45	2.41	2.36	2.34	2.22	2.14	2.07	1.94	1.83	1.72
542.00	1.43	1.50	1.55	1.66	1.70	1.76	1.80	1.84	1.87	1.89	1.90	1.90	1.89	1.87	1.84	1.82	1.75	1.70	1.65	1.57	1.50	1.43
642.00	1.13	1.18	1.21	1.27	1.29	1.33	1.35	1.37	1.39	1.40	1.41	1.41	1.40	1.39	1.37	1.37	1.33	1.29	1.27	1.22	1.18	1.13
742.00	0.91	0.94	0.96	1.00	1.01	1.03	1.05	1.06	1.07	1.08	1.08	1.08	1.08	1.07	1.06	1.05	1.03	1.01	1.00	0.97	0.94	0.91
842.00	0.74	0.76	0.77	0.80	0.81	0.82	0.83	0.84	0.84	0.85	0.85	0.85	0.85	0.85	0.84	0.84	0.82	0.81	0.80	0.78	0.76	0.74
942.00	0.61	0.63	0.63	0.65	0.66	0.67	0.67	0.68	0.68	0.68	0.69	0.69	0.69	0.68	0.68	0.68	0.67	0.66	0.65	0.64	0.63	0.62

Settlement Calculation, Best Estimated Rock Modulus, Line 5 (251.58' South)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.10**	**0.11**	**0.12**	**0.15**	**0.16**	**0.17**	**0.17**	**0.18**	**0.18**	**0.19**	**0.19**	**0.19**	**0.18**	**0.18**	**0.17**	**0.17**	**0.15**	**0.14**	**0.13**	**0.12**	**0.11**	**0.09**

Settlement Calculation, Best Estimated Rock Modulus, Line 5 (251.58' South)

Settlement Calculation, Best Estimated Rock Modulus, Line 5 (251.58' South)

SUMMARY OF SETTLEMENT							
Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	106.0	171.0	0.10	2	106.0	151.5	0.11
3	106.0	138.0	0.12	4	106.0	105.0	0.15
5	106.0	93.0	0.16	6	106.0	73.5	0.17
7	106.0	54.0	0.17	8	106.0	34.4	0.18
9	106.0	14.9	0.18	10	106.0	0.0	0.19
11	106.0	-24.1	0.19	12	106.0	-43.6	0.19
13	106.0	-63.1	0.18	14	106.0	-82.6	0.18
15	106.0	-102.1	0.17	16	106.0	-110.7	0.17
17	106.0	-141.1	0.15	18	106.0	-160.6	0.14
19	106.0	-174.7	0.13	20	106.0	-199.7	0.12
21	106.0	-219.2	0.11	22	106.0	-238.7	0.09

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, BERM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Best Estimated Rock Modulus, Line 6 (293.58' South)

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	148.0	171.0	2	148.0	151.5
3	148.0	138.0	4	148.0	105.0
5	148.0	93.0	6	148.0	73.5
7	148.0	54.0	8	148.0	34.4
9	148.0	14.9	10	148.0	0.0
11	148.0	-24.1	12	148.0	-43.6
13	148.0	-63.1	14	148.0	-82.6
15	148.0	-102.1	16	148.0	-110.7
17	148.0	-141.1	18	148.0	-160.6
19	148.0	-174.7	20	148.0	-199.7
21	148.0	-219.2	22	148.0	-238.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
19	417.50	33.00	110901	20	463.00	58.00	378268
21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

Settlement Calculation, Best Estimated Rock Modulus, Line 6 (293.58' South)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	3.65	7.14	7.27	8.25	9.10	9.21	9.22	9.23	9.23	9.23	9.23	9.23	9.22	9.20	8.81	7.45	5.69	5.67	5.67	5.65	5.55	2.83
70.00	3.47	5.83	6.55	7.78	8.27	8.66	8.78	8.82	8.84	8.84	8.84	8.82	8.75	8.53	7.74	7.14	5.70	5.48	5.40	5.18	4.54	2.72
92.50	3.21	4.72	5.52	6.91	7.31	7.76	8.00	8.12	8.17	8.18	8.17	8.10	7.94	7.60	6.98	6.63	5.57	5.18	4.96	4.46	3.71	2.56
107.00	3.08	4.29	5.02	6.39	6.77	7.23	7.51	7.68	7.76	7.78	7.75	7.67	7.48	7.13	6.61	6.33	5.43	4.99	4.71	4.11	3.41	2.50
120.50	3.00	4.01	4.67	5.96	6.33	6.79	7.10	7.29	7.39	7.43	7.40	7.30	7.10	6.77	6.31	6.08	5.28	4.83	4.51	3.87	3.22	2.45
149.00	2.86	3.62	4.13	5.23	5.56	6.00	6.33	6.55	6.68	6.73	6.71	6.61	6.42	6.14	5.78	5.61	4.94	4.50	4.17	3.54	2.99	2.40
183.00	2.73	3.30	3.69	4.57	4.85	5.24	5.55	5.77	5.92	5.97	5.97	5.89	5.73	5.51	5.23	5.09	4.53	4.14	3.84	3.29	2.83	2.37
214.50	2.61	3.06	3.37	4.09	4.32	4.65	4.93	5.13	5.27	5.33	5.35	5.29	5.16	4.98	4.75	4.64	4.17	3.83	3.57	3.10	2.71	2.33
239.00	2.52	2.89	3.16	3.77	3.97	4.26	4.50	4.69	4.82	4.88	4.90	4.86	4.75	4.60	4.40	4.31	3.90	3.60	3.38	2.96	2.62	2.29
264.00	2.41	2.74	2.96	3.48	3.65	3.90	4.12	4.28	4.40	4.46	4.48	4.45	4.37	4.24	4.07	3.99	3.63	3.38	3.18	2.82	2.52	2.23
294.00	2.29	2.55	2.74	3.17	3.31	3.52	3.70	3.84	3.95	4.00	4.03	4.00	3.94	3.83	3.70	3.63	3.33	3.12	2.95	2.65	2.40	2.15
324.00	2.16	2.38	2.54	2.89	3.01	3.19	3.34	3.46	3.55	3.59	3.62	3.60	3.55	3.47	3.36	3.30	3.06	2.88	2.74	2.48	2.27	2.06
355.00	2.03	2.21	2.34	2.64	2.73	2.88	3.00	3.11	3.18	3.22	3.24	3.23	3.19	3.13	3.04	2.99	2.79	2.64	2.53	2.31	2.13	1.95
386.00	1.90	2.05	2.16	2.41	2.49	2.61	2.71	2.80	2.86	2.89	2.92	2.91	2.88	2.82	2.75	2.71	2.55	2.42	2.33	2.15	2.00	1.85
417.50	1.77	1.90	1.99	2.20	2.26	2.36	2.45	2.52	2.57	2.60	2.62	2.62	2.59	2.55	2.49	2.46	2.32	2.22	2.14	1.99	1.86	1.74
463.00	1.60	1.71	1.77	1.93	1.98	2.06	2.13	2.18	2.22	2.24	2.26	2.26	2.24	2.21	2.16	2.14	2.04	1.96	1.90	1.78	1.68	1.58
542.00	1.34	1.41	1.46	1.56	1.59	1.64	1.68	1.72	1.75	1.76	1.77	1.77	1.76	1.74	1.71	1.70	1.63	1.58	1.54	1.47	1.40	1.34
642.00	1.08	1.12	1.15	1.21	1.23	1.26	1.29	1.31	1.32	1.33	1.34	1.34	1.33	1.32	1.30	1.30	1.26	1.23	1.21	1.16	1.12	1.08
742.00	0.88	0.90	0.92	0.96	0.97	0.99	1.01	1.02	1.03	1.03	1.04	1.04	1.03	1.03	1.02	1.01	0.99	0.97	0.96	0.93	0.90	0.88
842.00	0.72	0.74	0.75	0.77	0.78	0.79	0.80	0.81	0.82	0.82	0.82	0.82	0.82	0.82	0.81	0.81	0.79	0.78	0.77	0.75	0.74	0.72
942.00	0.60	0.61	0.62	0.64	0.64	0.65	0.66	0.66	0.67	0.67	0.67	0.67	0.67	0.67	0.66	0.66	0.65	0.64	0.64	0.62	0.61	0.60

Settlement Calculation, Best Estimated Rock Modulus, Line 6 (293.58' South)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
12	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
13	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.09**	**0.10**	**0.11**	**0.13**	**0.13**	**0.14**	**0.15**	**0.15**	**0.16**	**0.16**	**0.16**	**0.16**	**0.15**	**0.15**	**0.14**	**0.14**	**0.13**	**0.12**	**0.11**	**0.10**	**0.09**	**0.08**

Settlement Calculation, Best Estimated Rock Modulus, Line 6 (293.58' South)

Appendix E

Settlement Calculation, Best Estimated Rock Modulus, Line 6 (293.58' South)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	148.0	171.0	**0.09**	**2**	148.0	151.5	**0.10**
3	148.0	138.0	**0.11**	**4**	148.0	105.0	**0.13**
5	148.0	93.0	**0.13**	**6**	148.0	73.5	**0.14**
7	148.0	54.0	**0.15**	**8**	148.0	34.4	**0.15**
9	148.0	14.9	**0.16**	**10**	148.0	0.0	**0.16**
11	148.0	-24.1	**0.16**	**12**	148.0	-43.6	**0.16**
13	148.0	-63.1	**0.15**	**14**	148.0	-82.6	**0.15**
15	148.0	-102.1	**0.14**	**16**	148.0	-110.7	**0.14**
17	148.0	-141.1	**0.13**	**18**	148.0	-160.6	**0.12**
19	148.0	-174.7	**0.11**	**20**	148.0	-199.7	**0.10**
21	148.0	-219.2	**0.09**	**22**	148.0	-238.7	**0.08**

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, BERM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	185.2	171.0	2	185.2	151.5
3	185.2	138.0	4	185.2	105.0
5	185.2	93.0	6	185.2	73.5
7	185.2	54.0	8	185.2	34.4
9	185.2	14.9	10	185.2	0.0
11	185.2	-24.1	12	185.2	-43.6
13	185.2	-63.1	14	185.2	-82.6
15	185.2	-102.1	16	185.2	-110.7
17	185.2	-141.1	18	185.2	-160.6
19	185.2	-174.7	20	185.2	-199.7
21	185.2	-219.2	22	185.2	-238.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
19	417.50	33.00	110901	20	463.00	58.00	378268
21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

Settlement Calculation, Best Estimated Rock Modulus, Line 7 (South Boundary)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	1.83	3.58	3.64	4.07	4.43	4.48	4.48	4.49	4.49	4.49	4.49	4.49	4.48	4.47	4.31	3.75	3.02	3.01	3.00	3.00	2.94	1.50
70.00	1.85	3.07	3.46	4.04	4.26	4.44	4.50	4.52	4.53	4.53	4.53	4.51	4.48	4.37	4.02	3.76	3.12	3.01	2.97	2.84	2.49	1.50
92.50	1.90	2.75	3.20	3.95	4.15	4.38	4.50	4.57	4.60	4.60	4.59	4.55	4.47	4.29	3.97	3.80	3.26	3.05	2.92	2.62	2.18	1.52
107.00	1.94	2.66	3.08	3.86	4.07	4.32	4.48	4.57	4.62	4.63	4.62	4.56	4.45	4.26	3.97	3.83	3.33	3.07	2.90	2.53	2.10	1.55
120.50	1.98	2.60	3.00	3.78	3.99	4.26	4.44	4.55	4.62	4.63	4.62	4.55	4.43	4.24	3.97	3.84	3.36	3.09	2.89	2.48	2.07	1.59
149.00	2.04	2.54	2.88	3.59	3.80	4.09	4.30	4.44	4.52	4.55	4.54	4.47	4.35	4.17	3.93	3.82	3.38	3.09	2.87	2.44	2.07	1.68
183.00	2.08	2.48	2.75	3.37	3.56	3.83	4.04	4.20	4.30	4.34	4.33	4.27	4.16	4.01	3.81	3.71	3.31	3.04	2.82	2.42	2.10	1.77
214.50	2.07	2.41	2.64	3.16	3.33	3.58	3.77	3.92	4.02	4.06	4.07	4.03	3.93	3.80	3.63	3.54	3.19	2.94	2.75	2.39	2.10	1.82
239.00	2.05	2.34	2.54	3.00	3.15	3.37	3.55	3.69	3.79	3.83	3.85	3.81	3.73	3.61	3.46	3.39	3.07	2.85	2.67	2.35	2.09	1.84
264.00	2.01	2.26	2.44	2.84	2.97	3.17	3.33	3.46	3.55	3.59	3.61	3.58	3.51	3.41	3.28	3.21	2.94	2.74	2.58	2.29	2.06	1.83
294.00	1.94	2.16	2.31	2.65	2.77	2.93	3.07	3.19	3.27	3.31	3.33	3.30	3.25	3.17	3.06	3.00	2.76	2.59	2.46	2.21	2.01	1.81
324.00	1.86	2.05	2.18	2.47	2.57	2.71	2.83	2.93	3.00	3.03	3.05	3.04	3.00	2.93	2.83	2.79	2.59	2.44	2.32	2.11	1.94	1.76
355.00	1.78	1.94	2.04	2.29	2.37	2.49	2.60	2.68	2.74	2.77	2.79	2.78	2.75	2.69	2.61	2.57	2.41	2.28	2.18	2.00	1.85	1.70
386.00	1.69	1.82	1.91	2.12	2.19	2.29	2.38	2.45	2.50	2.53	2.55	2.54	2.51	2.47	2.40	2.37	2.23	2.12	2.04	1.89	1.76	1.63
417.50	1.59	1.71	1.79	1.96	2.02	2.11	2.18	2.24	2.28	2.31	2.32	2.32	2.30	2.26	2.21	2.18	2.06	1.97	1.90	1.77	1.66	1.55
463.00	1.46	1.55	1.61	1.75	1.80	1.86	1.92	1.97	2.00	2.02	2.04	2.03	2.02	1.99	1.95	1.93	1.84	1.77	1.71	1.61	1.52	1.43
542.00	1.25	1.31	1.35	1.44	1.47	1.52	1.56	1.59	1.61	1.62	1.63	1.63	1.62	1.61	1.58	1.57	1.51	1.46	1.43	1.36	1.30	1.24
642.00	1.02	1.06	1.08	1.14	1.16	1.19	1.21	1.23	1.24	1.25	1.26	1.26	1.25	1.24	1.23	1.22	1.18	1.16	1.14	1.09	1.06	1.02
742.00	0.84	0.86	0.88	0.92	0.93	0.94	0.96	0.97	0.98	0.99	0.99	0.99	0.99	0.98	0.97	0.97	0.94	0.93	0.91	0.89	0.86	0.84
842.00	0.69	0.71	0.72	0.75	0.75	0.76	0.77	0.78	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.77	0.75	0.75	0.73	0.71	0.70
942.00	0.58	0.59	0.60	0.62	0.62	0.63	0.64	0.64	0.64	0.65	0.65	0.65	0.65	0.65	0.64	0.64	0.63	0.62	0.62	0.60	0.59	0.58

Appendix E

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
12	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
13	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.07**	**0.08**	**0.09**	**0.10**	**0.10**	**0.11**	**0.11**	**0.12**	**0.12**	**0.12**	**0.12**	**0.12**	**0.12**	**0.12**	**0.11**	**0.11**	**0.10**	**0.10**	**0.09**	**0.08**	**0.08**	**0.07**

Settlement Calculation, Best Estimated Rock Modulus, Line 7 (South Boundary)

Appendix E

Settlement Calculation, Best Estimated Rock Modulus, Line 7 (South Boundary)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	185.2	171.0	**0.07**	**2**	185.2	151.5	**0.08**
3	185.2	138.0	**0.09**	**4**	185.2	105.0	**0.10**
5	185.2	93.0	**0.10**	**6**	185.2	73.5	**0.11**
7	185.2	54.0	**0.11**	**8**	185.2	34.4	**0.12**
9	185.2	14.9	**0.12**	**10**	185.2	0.0	**0.12**
11	185.2	-24.1	**0.12**	**12**	185.2	-43.6	**0.12**
13	185.2	-63.1	**0.12**	**14**	185.2	-82.6	**0.12**
15	185.2	-102.1	**0.11**	**16**	185.2	-110.7	**0.11**
17	185.2	-141.1	**0.10**	**18**	185.2	-160.6	**0.10**
19	185.2	-174.7	**0.09**	**20**	185.2	-199.7	**0.08**
21	185.2	-219.2	**0.08**	**22**	185.2	-238.7	**0.07**

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, BERM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\,\frac{m^2+n^2+2}{m^2+n^2+1} + \sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Best Estimated Rock Modulus, Line 8 (East Boundary)

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	171.0	2	-129.8	171.0
3	-114.1	171.0	4	-100.4	171.0
5	-82.6	171.0	6	-66.8	171.0
7	-51.1	171.0	8	-35.3	171.0
9	-19.6	171.0	10	0.0	171.0
11	14.2	171.0	12	27.7	171.0
13	43.4	171.0	14	59.2	171.0
15	74.9	171.0	16	90.7	171.0
17	106.0	171.0	18	122.2	171.0
19	137.9	171.0	20	148.0	171.0
21	169.4	171.0	22	185.2	171.0

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
19	417.50	33.00	110901	20	463.00	58.00	378268
21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

Settlement Calculation, Best Estimated Rock Modulus, Line 8 (East Boundary)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.17	1.84	3.48	3.64	3.65	3.66	3.66	3.66	3.66	3.65	3.65	3.53	1.83
70.00	0.10	0.13	0.15	0.17	0.19	0.21	0.23	0.29	0.43	1.01	1.96	2.88	3.42	3.60	3.66	3.67	3.66	3.63	3.56	3.47	2.89	1.85
92.50	0.38	0.47	0.55	0.61	0.68	0.74	0.83	0.96	1.20	1.75	2.31	2.84	3.29	3.55	3.66	3.69	3.65	3.56	3.38	3.21	2.57	1.90
107.00	0.61	0.73	0.84	0.94	1.05	1.15	1.27	1.43	1.68	2.15	2.56	2.95	3.31	3.55	3.66	3.68	3.62	3.49	3.28	3.08	2.49	1.94
120.50	0.82	0.96	1.11	1.23	1.37	1.50	1.64	1.82	2.06	2.45	2.77	3.07	3.36	3.55	3.64	3.65	3.58	3.43	3.19	3.00	2.45	1.98
149.00	1.19	1.38	1.56	1.71	1.90	2.07	2.24	2.42	2.62	2.89	3.09	3.26	3.43	3.54	3.57	3.54	3.45	3.28	3.04	2.86	2.41	2.04
183.00	1.51	1.70	1.90	2.06	2.26	2.44	2.61	2.77	2.93	3.11	3.23	3.33	3.40	3.44	3.43	3.37	3.26	3.09	2.89	2.73	2.37	2.08
214.50	1.68	1.87	2.06	2.21	2.41	2.57	2.72	2.86	2.99	3.12	3.20	3.26	3.29	3.29	3.26	3.18	3.07	2.92	2.74	2.61	2.31	2.07
239.00	1.76	1.94	2.11	2.25	2.43	2.58	2.72	2.84	2.95	3.05	3.11	3.15	3.16	3.15	3.11	3.03	2.93	2.79	2.63	2.52	2.25	2.05
264.00	1.80	1.96	2.11	2.25	2.41	2.54	2.66	2.77	2.86	2.94	2.98	3.01	3.01	2.99	2.94	2.87	2.78	2.65	2.51	2.41	2.18	2.01
294.00	1.80	1.94	2.08	2.19	2.33	2.45	2.55	2.64	2.71	2.78	2.81	2.82	2.82	2.79	2.75	2.68	2.60	2.49	2.37	2.29	2.09	1.94
324.00	1.77	1.89	2.01	2.11	2.23	2.33	2.41	2.49	2.55	2.60	2.62	2.63	2.62	2.60	2.56	2.50	2.42	2.33	2.23	2.16	1.99	1.86
355.00	1.72	1.82	1.93	2.01	2.11	2.19	2.26	2.32	2.37	2.41	2.43	2.43	2.43	2.40	2.37	2.31	2.25	2.17	2.09	2.03	1.89	1.78
386.00	1.65	1.74	1.83	1.90	1.98	2.05	2.11	2.16	2.20	2.23	2.25	2.25	2.24	2.22	2.19	2.14	2.09	2.02	1.95	1.90	1.78	1.69
417.50	1.57	1.65	1.72	1.78	1.86	1.91	1.96	2.00	2.03	2.06	2.07	2.07	2.06	2.05	2.02	1.98	1.93	1.88	1.82	1.77	1.67	1.59
463.00	1.45	1.51	1.57	1.62	1.68	1.72	1.76	1.79	1.81	1.83	1.84	1.84	1.83	1.82	1.80	1.77	1.73	1.69	1.64	1.60	1.52	1.46
542.00	1.25	1.29	1.33	1.36	1.40	1.43	1.45	1.47	1.49	1.50	1.50	1.50	1.50	1.49	1.47	1.45	1.43	1.40	1.37	1.34	1.29	1.25
642.00	1.03	1.05	1.08	1.09	1.12	1.13	1.15	1.16	1.17	1.18	1.18	1.18	1.17	1.17	1.16	1.15	1.13	1.11	1.09	1.08	1.05	1.02
742.00	0.84	0.86	0.87	0.89	0.90	0.91	0.92	0.93	0.93	0.94	0.94	0.94	0.94	0.93	0.93	0.92	0.91	0.90	0.88	0.88	0.85	0.84
842.00	0.70	0.71	0.72	0.73	0.74	0.74	0.75	0.75	0.76	0.76	0.76	0.76	0.76	0.76	0.75	0.75	0.74	0.73	0.73	0.72	0.71	0.69
942.00	0.58	0.59	0.60	0.60	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.63	0.63	0.62	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.58

Settlement Calculation, Best Estimated Rock Modulus, Line 8 (East Boundary)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
12	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
13	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.06**	**0.07**	**0.07**	**0.07**	**0.08**	**0.08**	**0.08**	**0.09**	**0.09**	**0.09**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.09**	**0.09**	**0.09**	**0.08**	**0.07**

Settlement Calculation, Best Estimated Rock Modulus, Line 8 (East Boundary)

Appendix E

Settlement Calculation, Best Estimated Rock Modulus, Line 8 (East Boundary)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-145.6	171.0	**0.06**	**2**	-129.8	171.0	**0.07**
3	-114.1	171.0	**0.07**	**4**	-100.4	171.0	**0.07**
5	-82.6	171.0	**0.08**	**6**	-66.8	171.0	**0.08**
7	-51.1	171.0	**0.08**	**8**	-35.3	171.0	**0.09**
9	-19.6	171.0	**0.09**	**10**	0.0	171.0	**0.09**
11	14.2	171.0	**0.10**	**12**	27.7	171.0	**0.10**
13	43.4	171.0	**0.10**	**14**	59.2	171.0	**0.10**
15	74.9	171.0	**0.10**	**16**	90.7	171.0	**0.10**
17	106.0	171.0	**0.10**	**18**	122.2	171.0	**0.09**
19	137.9	171.0	**0.09**	**20**	148.0	171.0	**0.09**
21	169.4	171.0	**0.08**	**22**	185.2	171.0	**0.07**

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, BERM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	138.0	2	-129.8	138.0
3	-114.1	138.0	4	-100.4	138.0
5	-82.6	138.0	6	-66.8	138.0
7	-51.1	138.0	8	-35.3	138.0
9	-19.6	138.0	10	0.0	138.0
11	14.2	138.0	12	27.7	138.0
13	43.4	138.0	14	59.2	138.0
15	74.9	138.0	16	90.7	138.0
17	106.0	138.0	18	122.2	138.0
19	137.9	138.0	20	148.0	138.0
21	169.4	138.0	22	185.2	138.0

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
19	417.50	33.00	110901	20	463.00	58.00	378268
21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

Settlement Calculation, Best Estimated Rock Modulus, Line 9 (33' West)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Depth (FT)	Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	0.03	0.05	0.06	0.06	0.07	0.07	0.07	0.08	0.10	0.38	3.69	6.96	7.26	7.30	7.30	7.30	7.30	7.29	7.28	7.27	7.03	3.64
70.00	0.50	0.69	0.82	0.89	0.95	0.98	1.02	1.11	1.33	2.34	4.08	5.75	6.69	6.98	7.05	7.04	6.98	6.88	6.73	6.55	5.47	3.46
92.50	1.16	1.50	1.78	1.96	2.12	2.24	2.37	2.56	2.90	3.72	4.58	5.39	6.07	6.42	6.54	6.52	6.40	6.18	5.84	5.52	4.40	3.20
107.00	1.49	1.85	2.18	2.40	2.64	2.81	2.98	3.21	3.55	4.19	4.77	5.32	5.81	6.10	6.20	6.17	6.02	5.75	5.36	5.02	4.02	3.08
120.50	1.72	2.09	2.43	2.68	2.96	3.17	3.38	3.62	3.94	4.45	4.87	5.25	5.61	5.83	5.90	5.85	5.68	5.40	5.00	4.67	3.77	3.00
149.00	2.04	2.39	2.73	3.00	3.31	3.56	3.80	4.04	4.30	4.62	4.86	5.06	5.24	5.33	5.34	5.25	5.06	4.78	4.41	4.13	3.43	2.88
183.00	2.24	2.55	2.85	3.10	3.41	3.65	3.88	4.09	4.28	4.50	4.63	4.73	4.80	4.81	4.76	4.65	4.47	4.22	3.91	3.69	3.16	2.75
214.50	2.31	2.58	2.84	3.06	3.33	3.55	3.75	3.92	4.08	4.23	4.31	4.36	4.39	4.37	4.30	4.18	4.02	3.80	3.55	3.37	2.96	2.64
239.00	2.31	2.54	2.78	2.97	3.21	3.41	3.58	3.73	3.86	3.98	4.04	4.07	4.08	4.05	3.97	3.86	3.72	3.53	3.31	3.16	2.81	2.54
264.00	2.28	2.48	2.69	2.86	3.07	3.24	3.39	3.51	3.62	3.72	3.76	3.78	3.78	3.74	3.67	3.57	3.44	3.27	3.09	2.96	2.66	2.44
294.00	2.21	2.38	2.56	2.70	2.88	3.02	3.14	3.25	3.33	3.41	3.44	3.45	3.44	3.40	3.34	3.25	3.14	3.00	2.85	2.74	2.50	2.31
324.00	2.12	2.27	2.41	2.53	2.68	2.80	2.90	2.98	3.05	3.11	3.14	3.14	3.13	3.09	3.04	2.96	2.87	2.75	2.62	2.54	2.33	2.18
355.00	2.01	2.13	2.26	2.36	2.48	2.57	2.66	2.73	2.78	2.83	2.85	2.85	2.84	2.81	2.76	2.69	2.62	2.52	2.41	2.34	2.17	2.04
386.00	1.90	2.00	2.10	2.19	2.29	2.37	2.44	2.49	2.54	2.57	2.59	2.59	2.58	2.55	2.51	2.45	2.39	2.31	2.22	2.16	2.02	1.91
417.50	1.78	1.87	1.95	2.02	2.11	2.17	2.23	2.27	2.31	2.34	2.35	2.35	2.34	2.32	2.28	2.24	2.18	2.12	2.04	1.99	1.88	1.79
463.00	1.62	1.69	1.75	1.81	1.87	1.92	1.96	2.00	2.02	2.04	2.05	2.05	2.04	2.02	2.00	1.96	1.92	1.87	1.81	1.77	1.68	1.61
542.00	1.36	1.41	1.45	1.48	1.52	1.56	1.58	1.60	1.62	1.63	1.64	1.64	1.63	1.62	1.60	1.58	1.55	1.52	1.48	1.46	1.40	1.35
642.00	1.09	1.12	1.15	1.17	1.19	1.21	1.23	1.24	1.25	1.26	1.26	1.26	1.25	1.25	1.24	1.22	1.21	1.19	1.16	1.15	1.11	1.08
742.00	0.89	0.90	0.92	0.93	0.95	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.98	0.98	0.97	0.97	0.96	0.94	0.93	0.92	0.90	0.88
842.00	0.73	0.74	0.75	0.76	0.77	0.77	0.78	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.77	0.76	0.75	0.75	0.73	0.72
942.00	0.60	0.61	0.62	0.62	0.63	0.64	0.64	0.64	0.65	0.65	0.65	0.65	0.65	0.64	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.60

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
12	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
13	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.08**	**0.08**	**0.09**	**0.09**	**0.10**	**0.10**	**0.11**	**0.11**	**0.12**	**0.12**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.12**	**0.12**	**0.11**	**0.11**	**0.10**	**0.09**

Settlement Calculation, Best Estimated Rock Modulus, Line 9 (33' West)

Settlement Calculation, Best Estimated Rock Modulus, Line 9 (33' West)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-145.6	138.0	**0.08**	**2**	-129.8	138.0	**0.08**
3	-114.1	138.0	**0.09**	**4**	-100.4	138.0	**0.09**
5	-82.6	138.0	**0.10**	**6**	-66.8	138.0	**0.10**
7	-51.1	138.0	**0.11**	**8**	-35.3	138.0	**0.11**
9	-19.6	138.0	**0.12**	**10**	0.0	138.0	**0.12**
11	14.2	138.0	**0.13**	**12**	27.7	138.0	**0.13**
13	43.4	138.0	**0.13**	**14**	59.2	138.0	**0.13**
15	74.9	138.0	**0.13**	**16**	90.7	138.0	**0.13**
17	106.0	138.0	**0.12**	**18**	122.2	138.0	**0.12**
19	137.9	138.0	**0.11**	**20**	148.0	138.0	**0.11**
21	169.4	138.0	**0.10**	**22**	185.2	138.0	**0.09**

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, BERM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\,\frac{m^2+n^2+2}{m^2+n^2+1} + \sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	105.0	2	-129.8	105.0
3	-114.1	105.0	4	-100.4	105.0
5	-82.6	105.0	6	-66.8	105.0
7	-51.1	105.0	8	-35.3	105.0
9	-19.6	105.0	10	0.0	105.0
11	14.2	105.0	12	27.7	105.0
13	43.4	105.0	14	59.2	105.0
15	74.9	105.0	16	90.7	105.0
17	106.0	105.0	18	122.2	105.0
19	137.9	105.0	20	148.0	105.0
21	169.4	105.0	22	185.2	105.0

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
19	417.50	33.00	110901	20	463.00	58.00	378268
21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

Settlement Calculation, Best Estimated Rock Modulus, Line 10 (66' West)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	3.27	6.30	6.50	6.52	6.53	6.54	6.54	6.54	6.55	6.70	8.36	10.01	10.16	10.18	10.18	10.12	9.30	8.47	8.39	8.25	7.85	4.07
70.00	3.27	5.13	5.99	6.28	6.43	6.49	6.54	6.60	6.75	7.33	8.28	9.19	9.71	9.87	9.84	9.61	9.10	8.51	8.09	7.78	6.39	4.04
92.50	3.26	4.44	5.31	5.79	6.14	6.33	6.48	6.65	6.91	7.46	8.01	8.52	8.94	9.12	9.09	8.87	8.49	7.98	7.39	6.91	5.44	3.95
107.00	3.26	4.20	4.98	5.48	5.91	6.18	6.39	6.61	6.89	7.36	7.76	8.13	8.44	8.58	8.55	8.34	7.99	7.49	6.88	6.39	5.06	3.86
120.50	3.24	4.04	4.74	5.23	5.70	6.01	6.26	6.51	6.79	7.19	7.50	7.77	8.00	8.09	8.04	7.84	7.51	7.03	6.42	5.96	4.77	3.78
149.00	3.20	3.80	4.36	4.79	5.26	5.60	5.90	6.16	6.41	6.70	6.89	7.03	7.14	7.15	7.06	6.86	6.56	6.13	5.61	5.23	4.31	3.59
183.00	3.12	3.57	4.01	4.36	4.77	5.09	5.37	5.61	5.82	6.03	6.14	6.21	6.24	6.20	6.08	5.89	5.63	5.27	4.86	4.57	3.89	3.37
214.50	3.00	3.37	3.72	4.01	4.36	4.63	4.87	5.08	5.25	5.40	5.47	5.51	5.51	5.45	5.33	5.16	4.93	4.64	4.32	4.09	3.56	3.16
239.00	2.90	3.20	3.50	3.75	4.05	4.29	4.50	4.67	4.82	4.94	5.00	5.02	5.00	4.94	4.83	4.67	4.48	4.23	3.96	3.77	3.33	3.00
264.00	2.77	3.03	3.29	3.50	3.76	3.96	4.14	4.28	4.40	4.51	4.55	4.56	4.54	4.48	4.38	4.24	4.08	3.87	3.64	3.48	3.12	2.84
294.00	2.62	2.83	3.04	3.22	3.43	3.59	3.74	3.86	3.95	4.03	4.06	4.07	4.05	3.99	3.91	3.79	3.66	3.49	3.30	3.17	2.88	2.65
324.00	2.46	2.64	2.81	2.95	3.12	3.26	3.38	3.47	3.55	3.61	3.64	3.64	3.62	3.57	3.50	3.40	3.29	3.15	3.00	2.89	2.65	2.47
355.00	2.29	2.44	2.58	2.70	2.84	2.95	3.04	3.12	3.18	3.23	3.25	3.25	3.23	3.19	3.13	3.05	2.96	2.85	2.72	2.64	2.44	2.29
386.00	2.13	2.25	2.37	2.47	2.58	2.67	2.75	2.81	2.86	2.90	2.91	2.91	2.89	2.86	2.81	2.75	2.67	2.58	2.48	2.41	2.25	2.12
417.50	1.98	2.08	2.17	2.25	2.35	2.42	2.48	2.53	2.57	2.60	2.61	2.61	2.60	2.57	2.53	2.48	2.41	2.34	2.25	2.20	2.06	1.96
463.00	1.77	1.85	1.92	1.98	2.05	2.10	2.15	2.19	2.22	2.24	2.25	2.25	2.24	2.21	2.18	2.14	2.10	2.04	1.98	1.93	1.83	1.75
542.00	1.46	1.51	1.56	1.59	1.64	1.67	1.70	1.72	1.74	1.76	1.76	1.76	1.75	1.74	1.72	1.69	1.66	1.63	1.59	1.56	1.50	1.44
642.00	1.15	1.18	1.21	1.23	1.26	1.28	1.30	1.31	1.32	1.33	1.33	1.33	1.32	1.32	1.30	1.29	1.27	1.25	1.23	1.21	1.17	1.14
742.00	0.92	0.94	0.96	0.97	0.99	1.00	1.01	1.02	1.03	1.03	1.03	1.03	1.03	1.02	1.02	1.01	1.00	0.98	0.97	0.96	0.94	0.92
842.00	0.75	0.76	0.77	0.78	0.79	0.80	0.81	0.81	0.82	0.82	0.82	0.82	0.82	0.82	0.81	0.81	0.80	0.79	0.78	0.77	0.76	0.75
942.00	0.62	0.63	0.64	0.64	0.65	0.65	0.66	0.66	0.66	0.67	0.67	0.67	0.66	0.66	0.66	0.66	0.65	0.65	0.64	0.64	0.62	0.62

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.10**	**0.11**	**0.12**	**0.12**	**0.13**	**0.14**	**0.14**	**0.15**	**0.15**	**0.15**	**0.16**	**0.16**	**0.16**	**0.16**	**0.16**	**0.15**	**0.15**	**0.14**	**0.13**	**0.13**	**0.11**	**0.10**

Settlement Calculation, Best Estimated Rock Modulus, Line 10 (66' West)

Settlement Calculation, Best Estimated Rock Modulus, Line 10 (66' West)

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1	-145.6	105.0	**0.10**	**2**	-129.8	105.0	**0.11**
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9	-19.6	105.0	**0.15**	**10**	0.0	105.0	**0.15**
11	14.2	105.0	**0.16**	**12**	27.7	105.0	**0.16**
13	43.4	105.0	**0.16**	**14**	59.2	105.0	**0.16**
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This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\,\frac{m^2+n^2+2}{m^2+n^2+1} + \sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Best Estimated Rock Modulus, Line 11 (171' West)

SUMMARY OF INPUT

Number of Loaded Areas= 9 **Number of Soil Layers=** 25 **Number of Settlement Points=** 22

Poisson's Ratio= 0.30 **Stress distribution code=** 1 **Depth of Grondwater Table=** 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	0.0	2	-129.8	0.0
3	-114.1	0.0	4	-100.4	0.0
5	-82.6	0.0	6	-66.8	0.0
7	-51.1	0.0	8	-35.3	0.0
9	-19.6	0.0	10	0.0	0.0
11	14.2	0.0	12	27.7	0.0
13	43.4	0.0	14	59.2	0.0
15	74.9	0.0	16	90.7	0.0
17	106.0	0.0	18	122.2	0.0
19	137.9	0.0	20	148.0	0.0
21	169.4	0.0	22	185.2	0.0

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
19	417.50	33.00	110901	20	463.00	58.00	378268
21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

Settlement Calculation, Best Estimated Rock Modulus, Line 11 (171' West)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	6.54	12.60	12.99	13.05	13.06	13.07	13.07	13.07	13.07	13.07	13.07	13.07	13.07	13.07	13.05	12.94	11.30	9.64	9.49	9.23	8.66	4.49
70.00	6.50	10.22	11.93	12.50	12.78	12.88	12.93	12.95	12.97	12.97	12.97	12.96	12.93	12.86	12.68	12.18	11.15	10.01	9.30	8.84	7.16	4.53
92.50	6.35	8.68	10.39	11.29	11.95	12.25	12.41	12.51	12.56	12.58	12.58	12.54	12.46	12.29	11.97	11.43	10.67	9.76	8.84	8.18	6.35	4.60
107.00	6.20	8.04	9.54	10.47	11.25	11.65	11.90	12.05	12.13	12.17	12.16	12.12	12.00	11.79	11.44	10.91	10.23	9.39	8.45	7.78	6.07	4.63
120.50	6.03	7.55	8.86	9.75	10.56	11.03	11.33	11.53	11.64	11.70	11.69	11.64	11.50	11.27	10.91	10.41	9.77	8.97	8.07	7.43	5.87	4.63
149.00	5.60	6.68	7.67	8.40	9.17	9.67	10.03	10.28	10.44	10.54	10.53	10.47	10.33	10.09	9.75	9.29	8.74	8.05	7.27	6.73	5.49	4.55
183.00	5.07	5.83	6.54	7.10	7.73	8.18	8.53	8.79	8.97	9.08	9.09	9.03	8.90	8.69	8.39	8.01	7.56	7.00	6.39	5.97	5.03	4.34
214.50	4.59	5.16	5.70	6.14	6.64	7.02	7.32	7.56	7.72	7.83	7.84	7.80	7.69	7.51	7.27	6.95	6.59	6.14	5.66	5.33	4.61	4.06
239.00	4.24	4.70	5.15	5.50	5.92	6.24	6.51	6.71	6.86	6.96	6.97	6.94	6.85	6.70	6.49	6.22	5.92	5.55	5.15	4.88	4.28	3.83
264.00	3.91	4.29	4.65	4.95	5.29	5.56	5.78	5.96	6.09	6.18	6.19	6.16	6.09	5.96	5.79	5.57	5.31	5.01	4.68	4.46	3.96	3.59
294.00	3.55	3.85	4.13	4.37	4.65	4.86	5.04	5.18	5.29	5.36	5.38	5.36	5.30	5.20	5.06	4.88	4.68	4.44	4.17	4.00	3.60	3.31
324.00	3.22	3.46	3.69	3.88	4.10	4.27	4.41	4.53	4.62	4.68	4.69	4.67	4.63	4.55	4.44	4.30	4.13	3.94	3.73	3.59	3.27	3.03
355.00	2.92	3.11	3.29	3.44	3.62	3.75	3.87	3.96	4.03	4.08	4.09	4.08	4.04	3.98	3.89	3.78	3.65	3.50	3.33	3.22	2.96	2.77
386.00	2.64	2.80	2.94	3.06	3.21	3.32	3.41	3.48	3.54	3.58	3.59	3.58	3.55	3.50	3.43	3.34	3.24	3.12	2.98	2.89	2.69	2.53
417.50	2.40	2.52	2.64	2.74	2.85	2.94	3.01	3.07	3.12	3.15	3.16	3.15	3.13	3.09	3.03	2.96	2.88	2.78	2.67	2.60	2.43	2.31
463.00	2.09	2.18	2.27	2.34	2.43	2.49	2.54	2.59	2.62	2.64	2.65	2.64	2.63	2.60	2.56	2.51	2.45	2.38	2.30	2.24	2.12	2.02
542.00	1.66	1.72	1.78	1.82	1.87	1.91	1.94	1.97	1.99	2.00	2.00	2.00	1.99	1.98	1.95	1.92	1.89	1.84	1.79	1.76	1.68	1.62
642.00	1.27	1.31	1.34	1.36	1.39	1.41	1.43	1.45	1.46	1.47	1.47	1.47	1.46	1.45	1.44	1.42	1.40	1.38	1.35	1.33	1.29	1.25
742.00	1.00	1.02	1.04	1.05	1.07	1.08	1.09	1.10	1.11	1.11	1.11	1.11	1.11	1.11	1.10	1.09	1.08	1.06	1.04	1.03	1.01	0.99
842.00	0.80	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.86	0.86	0.85	0.84	0.83	0.82	0.80	0.79
942.00	0.65	0.66	0.67	0.68	0.68	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.65

Settlement Calculation, Best Estimated Rock Modulus, Line 11 (171' West)

Appendix E

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
6	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
7	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
8	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
9	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
10	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
11	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.14**	**0.16**	**0.17**	**0.18**	**0.19**	**0.20**	**0.20**	**0.21**	**0.21**	**0.21**	**0.21**	**0.21**	**0.21**	**0.21**	**0.20**	**0.20**	**0.19**	**0.18**	**0.16**	**0.16**	**0.14**	**0.12**

Settlement Calculation, Best Estimated Rock Modulus, Line 11 (171' West)

Appendix E

Settlement Calculation, Best Estimated Rock Modulus, Line 11 (171' West)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-145.6	0.0	**0.14**	**2**	-129.8	0.0	**0.16**
3	-114.1	0.0	**0.17**	**4**	-100.4	0.0	**0.18**
5	-82.6	0.0	**0.19**	**6**	-66.8	0.0	**0.20**
7	-51.1	0.0	**0.20**	**8**	-35.3	0.0	**0.21**
9	-19.6	0.0	**0.21**	**10**	0.0	0.0	**0.21**
11	14.2	0.0	**0.21**	**12**	27.7	0.0	**0.21**
13	43.4	0.0	**0.21**	**14**	59.2	0.0	**0.21**
15	74.9	0.0	**0.20**	**16**	90.7	0.0	**0.20**
17	106.0	0.0	**0.19**	**18**	122.2	0.0	**0.18**
19	137.9	0.0	**0.16**	**20**	148.0	0.0	**0.16**
21	169.4	0.0	**0.14**	**22**	185.2	0.0	**0.12**

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, BERM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Best Estimated Rock Modulus, Line 12 (281.665' West)

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	-110.7	2	-129.8	-110.7
3	-114.1	-110.7	4	-100.4	-110.7
5	-82.6	-110.7	6	-66.8	-110.7
7	-51.1	-110.7	8	-35.3	-110.7
9	-19.6	-110.7	10	0.0	-110.7
11	14.2	-110.7	12	27.7	-110.7
13	43.4	-110.7	14	59.2	-110.7
15	74.9	-110.7	16	90.7	-110.7
17	106.0	-110.7	18	122.2	-110.7
19	137.9	-110.7	20	148.0	-110.7
21	169.4	-110.7	22	185.2	-110.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
19	417.50	33.00	110901	20	463.00	58.00	378268
21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

Settlement Calculation, Best Estimated Rock Modulus, Line 12 (281.665' West)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	5.65	10.88	11.19	10.84	10.45	10.44	10.44	10.44	10.44	10.44	10.44	10.44	10.44	10.43	10.42	10.32	8.94	7.54	7.45	7.45	7.22	3.75
70.00	5.60	8.77	10.13	10.40	10.38	10.37	10.37	10.38	10.38	10.39	10.38	10.37	10.34	10.29	10.13	9.71	8.85	7.93	7.42	7.14	5.91	3.76
92.50	5.47	7.43	8.79	9.45	9.86	10.02	10.10	10.15	10.17	10.17	10.16	10.12	10.04	9.90	9.63	9.17	8.56	7.83	7.12	6.63	5.21	3.80
107.00	5.37	6.90	8.12	8.83	9.38	9.64	9.80	9.88	9.93	9.94	9.92	9.86	9.75	9.57	9.27	8.83	8.27	7.59	6.86	6.33	4.99	3.83
120.50	5.25	6.52	7.59	8.29	8.91	9.24	9.45	9.57	9.64	9.65	9.63	9.56	9.43	9.22	8.91	8.49	7.96	7.32	6.60	6.08	4.84	3.84
149.00	4.97	5.88	6.70	7.31	7.92	8.31	8.58	8.76	8.86	8.90	8.88	8.80	8.65	8.43	8.13	7.73	7.27	6.69	6.05	5.61	4.59	3.82
183.00	4.59	5.24	5.86	6.34	6.86	7.23	7.50	7.70	7.82	7.88	7.86	7.80	7.66	7.45	7.18	6.84	6.44	5.96	5.44	5.09	4.30	3.71
214.50	4.22	4.72	5.20	5.58	6.01	6.32	6.57	6.76	6.88	6.94	6.93	6.88	6.76	6.58	6.35	6.06	5.73	5.34	4.92	4.64	4.01	3.54
239.00	3.94	4.35	4.75	5.06	5.43	5.70	5.92	6.08	6.20	6.26	6.25	6.21	6.11	5.96	5.76	5.51	5.23	4.90	4.54	4.31	3.78	3.39
264.00	3.67	4.01	4.33	4.59	4.90	5.13	5.32	5.46	5.56	5.62	5.62	5.58	5.50	5.37	5.20	5.00	4.76	4.48	4.19	3.99	3.54	3.21
294.00	3.35	3.63	3.89	4.10	4.34	4.53	4.69	4.81	4.89	4.94	4.94	4.92	4.85	4.75	4.61	4.44	4.25	4.03	3.79	3.63	3.27	3.00
324.00	3.06	3.28	3.49	3.66	3.86	4.01	4.14	4.24	4.31	4.35	4.36	4.34	4.28	4.20	4.09	3.96	3.80	3.62	3.43	3.30	3.01	2.79
355.00	2.79	2.97	3.13	3.27	3.43	3.55	3.66	3.74	3.79	3.83	3.84	3.82	3.78	3.71	3.63	3.52	3.40	3.25	3.09	2.99	2.75	2.57
386.00	2.54	2.68	2.82	2.93	3.06	3.16	3.24	3.31	3.35	3.39	3.39	3.38	3.34	3.29	3.22	3.14	3.04	2.92	2.80	2.71	2.52	2.37
417.50	2.31	2.43	2.54	2.63	2.73	2.81	2.88	2.93	2.97	3.00	3.00	2.99	2.97	2.93	2.87	2.80	2.72	2.63	2.53	2.46	2.30	2.18
463.00	2.02	2.11	2.19	2.26	2.34	2.40	2.45	2.49	2.52	2.54	2.54	2.53	2.52	2.49	2.45	2.40	2.34	2.27	2.19	2.14	2.02	1.93
542.00	1.62	1.68	1.73	1.77	1.82	1.85	1.88	1.91	1.93	1.94	1.94	1.94	1.93	1.91	1.89	1.86	1.82	1.78	1.73	1.70	1.62	1.57
642.00	1.25	1.28	1.31	1.33	1.36	1.38	1.40	1.41	1.42	1.43	1.43	1.43	1.43	1.42	1.40	1.39	1.37	1.34	1.31	1.30	1.25	1.22
742.00	0.98	1.00	1.02	1.04	1.05	1.06	1.07	1.08	1.09	1.09	1.09	1.09	1.09	1.08	1.08	1.07	1.05	1.04	1.02	1.01	0.99	0.97
842.00	0.79	0.80	0.81	0.82	0.83	0.84	0.85	0.85	0.86	0.86	0.86	0.86	0.86	0.85	0.85	0.84	0.84	0.83	0.82	0.81	0.79	0.78
942.00	0.65	0.65	0.66	0.67	0.67	0.68	0.68	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.68	0.68	0.67	0.66	0.66	0.65	0.64

Settlement Calculation, Best Estimated Rock Modulus, Line 12 (281.665' West)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
8	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
9	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.13**	**0.14**	**0.16**	**0.16**	**0.17**	**0.18**	**0.18**	**0.19**	**0.19**	**0.19**	**0.19**	**0.19**	**0.19**	**0.18**	**0.18**	**0.17**	**0.17**	**0.16**	**0.15**	**0.14**	**0.12**	**0.11**

Settlement Calculation, Best Estimated Rock Modulus, Line 12 (281.665' West)

Appendix E

Settlement Calculation, Best Estimated Rock Modulus, Line 12 (281.665' West)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-145.6	-110.7	0.13	2	-129.8	-110.7	0.14
3	-114.1	-110.7	0.16	4	-100.4	-110.7	0.16
5	-82.6	-110.7	0.17	6	-66.8	-110.7	0.18
7	-51.1	-110.7	0.18	8	-35.3	-110.7	0.19
9	-19.6	-110.7	0.19	10	0.0	-110.7	0.19
11	14.2	-110.7	0.19	12	27.7	-110.7	0.19
13	43.4	-110.7	0.19	14	59.2	-110.7	0.18
15	74.9	-110.7	0.18	16	90.7	-110.7	0.17
17	106.0	-110.7	0.17	18	122.2	-110.7	0.16
19	137.9	-110.7	0.15	20	148.0	-110.7	0.14
21	169.4	-110.7	0.12	22	185.2	-110.7	0.11

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, BERM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Best Estimated Rock Modulus, Line 13 (345.668' West)

SUMMARY OF INPUT

Number of Loaded Areas= 9 **Number of Soil Layers=** 25 **Number of Settlement Points=** 22

Poisson's Ratio= 0.30 **Stress distribution code=** 1 **Depth of Grondwater Table=** 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	-174.7	2	-129.8	-174.7
3	-114.1	-174.7	4	-100.4	-174.7
5	-82.6	-174.7	6	-66.8	-174.7
7	-51.1	-174.7	8	-35.3	-174.7
9	-19.6	-174.7	10	0.0	-174.7
11	14.2	-174.7	12	27.7	-174.7
13	43.4	-174.7	14	59.2	-174.7
15	74.9	-174.7	16	90.7	-174.7
17	106.0	-174.7	18	122.2	-174.7
19	137.9	-174.7	20	148.0	-174.7
21	169.4	-174.7	22	185.2	-174.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
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21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

Settlement Calculation, Best Estimated Rock Modulus, Line 13 (345.668' West)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	4.75	9.16	9.37	8.64	7.84	7.81	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.79	7.71	6.58	5.44	5.41	5.67	5.79	3.00
70.00	4.65	7.26	8.25	8.22	7.90	7.78	7.75	7.74	7.74	7.74	7.73	7.72	7.70	7.66	7.54	7.20	6.51	5.80	5.50	5.40	4.64	2.97
92.50	4.41	5.96	6.96	7.35	7.50	7.52	7.52	7.53	7.53	7.53	7.51	7.48	7.42	7.31	7.10	6.75	6.28	5.76	5.28	4.96	3.97	2.92
107.00	4.24	5.43	6.32	6.79	7.10	7.22	7.29	7.32	7.33	7.33	7.31	7.27	7.18	7.04	6.81	6.48	6.07	5.58	5.07	4.71	3.76	2.90
120.50	4.10	5.07	5.85	6.33	6.72	6.91	7.02	7.08	7.11	7.11	7.09	7.04	6.94	6.78	6.55	6.23	5.85	5.38	4.87	4.51	3.62	2.89
149.00	3.83	4.51	5.12	5.55	5.97	6.23	6.41	6.52	6.58	6.60	6.57	6.51	6.40	6.23	6.00	5.71	5.37	4.95	4.49	4.17	3.43	2.87
183.00	3.55	4.05	4.50	4.85	5.23	5.49	5.69	5.82	5.90	5.94	5.92	5.86	5.75	5.60	5.39	5.14	4.84	4.49	4.10	3.84	3.26	2.82
214.50	3.32	3.70	4.06	4.34	4.66	4.89	5.08	5.21	5.29	5.33	5.32	5.27	5.18	5.05	4.87	4.65	4.40	4.10	3.79	3.57	3.10	2.75
239.00	3.15	3.46	3.76	4.00	4.28	4.48	4.65	4.77	4.85	4.89	4.88	4.84	4.76	4.64	4.49	4.30	4.09	3.83	3.56	3.38	2.97	2.67
264.00	2.97	3.24	3.49	3.69	3.93	4.10	4.25	4.36	4.43	4.47	4.47	4.43	4.37	4.26	4.13	3.97	3.78	3.57	3.34	3.18	2.84	2.58
294.00	2.77	2.99	3.19	3.36	3.55	3.70	3.82	3.91	3.97	4.01	4.01	3.99	3.93	3.85	3.74	3.60	3.45	3.27	3.08	2.95	2.67	2.46
324.00	2.57	2.75	2.92	3.06	3.22	3.34	3.44	3.52	3.57	3.60	3.60	3.58	3.54	3.47	3.38	3.27	3.15	3.00	2.84	2.74	2.50	2.32
355.00	2.38	2.53	2.67	2.78	2.91	3.01	3.09	3.15	3.20	3.23	3.23	3.21	3.18	3.12	3.05	2.96	2.86	2.74	2.61	2.53	2.33	2.18
386.00	2.20	2.32	2.43	2.53	2.63	2.72	2.78	2.84	2.87	2.90	2.90	2.89	2.86	2.82	2.76	2.69	2.60	2.50	2.40	2.33	2.17	2.04
417.50	2.03	2.13	2.22	2.30	2.39	2.45	2.51	2.55	2.59	2.61	2.61	2.60	2.58	2.54	2.49	2.43	2.37	2.29	2.20	2.14	2.01	1.90
463.00	1.81	1.88	1.95	2.01	2.08	2.13	2.17	2.21	2.23	2.25	2.25	2.24	2.23	2.20	2.16	2.12	2.07	2.01	1.94	1.90	1.79	1.71
542.00	1.48	1.53	1.58	1.61	1.66	1.69	1.71	1.74	1.75	1.76	1.76	1.76	1.75	1.73	1.71	1.68	1.65	1.61	1.57	1.54	1.48	1.43
642.00	1.17	1.19	1.22	1.24	1.27	1.29	1.30	1.32	1.32	1.33	1.33	1.33	1.32	1.32	1.30	1.29	1.27	1.25	1.22	1.21	1.17	1.14
742.00	0.93	0.95	0.97	0.98	0.99	1.01	1.02	1.02	1.03	1.03	1.03	1.03	1.03	1.02	1.02	1.01	1.00	0.98	0.97	0.96	0.93	0.91
842.00	0.76	0.77	0.78	0.79	0.80	0.80	0.81	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.81	0.81	0.80	0.79	0.78	0.77	0.76	0.75
942.00	0.62	0.63	0.64	0.64	0.65	0.66	0.66	0.66	0.67	0.67	0.67	0.67	0.67	0.66	0.66	0.66	0.65	0.65	0.64	0.64	0.62	0.62

Settlement Calculation, Best Estimated Rock Modulus, Line 13 (345.668' West)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.11**	**0.12**	**0.13**	**0.13**	**0.14**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.14**	**0.14**	**0.13**	**0.13**	**0.12**	**0.11**	**0.10**	**0.09**

Settlement Calculation, Best Estimated Rock Modulus, Line 13 (345.668' West)

Appendix E

Settlement Calculation, Best Estimated Rock Modulus, Line 13 (345.668' West)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-145.6	-174.7	**0.11**	**2**	-129.8	-174.7	**0.12**
3	-114.1	-174.7	**0.13**	**4**	-100.4	-174.7	**0.13**
5	-82.6	-174.7	**0.14**	**6**	-66.8	-174.7	**0.15**
7	-51.1	-174.7	**0.15**	**8**	-35.3	-174.7	**0.15**
9	-19.6	-174.7	**0.15**	**10**	0.0	-174.7	**0.15**
11	14.2	-174.7	**0.15**	**12**	27.7	-174.7	**0.15**
13	43.4	-174.7	**0.15**	**14**	59.2	-174.7	**0.15**
15	74.9	-174.7	**0.14**	**16**	90.7	-174.7	**0.14**
17	106.0	-174.7	**0.13**	**18**	122.2	-174.7	**0.13**
19	137.9	-174.7	**0.12**	**20**	148.0	-174.7	**0.11**
21	169.4	-174.7	**0.10**	**22**	185.2	-174.7	**0.09**

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, BERM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	-238.7	2	-129.8	-238.7
3	-114.1	-238.7	4	-100.4	-238.7
5	-82.6	-238.7	6	-66.8	-238.7
7	-51.1	-238.7	8	-35.3	-238.7
9	-19.6	-238.7	10	0.0	-238.7
11	14.2	-238.7	12	27.7	-238.7
13	43.4	-238.7	14	59.2	-238.7
15	74.9	-238.7	16	90.7	-238.7
17	106.0	-238.7	18	122.2	-238.7
19	137.9	-238.7	20	148.0	-238.7
21	169.4	-238.7	22	185.2	-238.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	155548	2	15.00	18.00	155548
3	28.00	8.00	44263	4	36.00	8.00	44263
5	50.00	20.00	405550	6	70.00	20.00	405550
7	92.50	25.00	405550	8	107.00	4.00	59688
9	120.50	23.00	313510	10	149.00	34.00	585033
11	183.00	34.00	205856	12	214.50	29.00	72539
13	239.00	20.00	110220	14	264.00	30.00	110220
15	294.00	30.00	110220	16	324.00	30.00	117959
17	355.00	32.00	117959	18	386.00	30.00	110901
19	417.50	33.00	110901	20	463.00	58.00	378268
21	542.00	100.00	378268	22	642.00	100.00	378268
23	742.00	100.00	378268	24	842.00	100.00	378268
25	942.00	100.00	378268				

Settlement Calculation, Best Estimated Rock Modulus, Line 14 (West Boundary)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Depth (FT)	Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	2.38	4.58	4.69	4.32	3.92	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.89	3.85	3.29	2.72	2.71	2.83	2.89	1.50
70.00	2.35	3.66	4.16	4.15	3.99	3.92	3.91	3.90	3.90	3.90	3.90	3.89	3.88	3.86	3.80	3.63	3.28	2.92	2.77	2.72	2.34	1.50
92.50	2.30	3.09	3.60	3.80	3.88	3.89	3.89	3.89	3.90	3.89	3.88	3.87	3.83	3.77	3.66	3.48	3.24	2.97	2.73	2.56	2.06	1.52
107.00	2.27	2.89	3.35	3.60	3.76	3.82	3.86	3.87	3.88	3.88	3.86	3.84	3.79	3.72	3.60	3.42	3.21	2.95	2.68	2.50	2.00	1.55
120.50	2.26	2.77	3.19	3.44	3.65	3.75	3.81	3.84	3.86	3.86	3.84	3.81	3.75	3.67	3.54	3.37	3.16	2.92	2.64	2.45	1.98	1.59
149.00	2.24	2.62	2.96	3.19	3.43	3.58	3.67	3.74	3.77	3.78	3.76	3.72	3.66	3.56	3.43	3.27	3.07	2.84	2.58	2.40	1.99	1.68
183.00	2.23	2.52	2.78	2.99	3.21	3.36	3.48	3.56	3.61	3.62	3.61	3.58	3.51	3.41	3.29	3.14	2.96	2.75	2.53	2.37	2.03	1.77
214.50	2.20	2.43	2.65	2.83	3.03	3.17	3.28	3.36	3.41	3.44	3.43	3.40	3.34	3.25	3.14	3.00	2.85	2.66	2.47	2.33	2.04	1.82
239.00	2.16	2.36	2.56	2.71	2.89	3.02	3.12	3.20	3.25	3.27	3.27	3.24	3.19	3.11	3.01	2.89	2.75	2.58	2.41	2.29	2.03	1.84
264.00	2.11	2.29	2.45	2.59	2.74	2.86	2.95	3.03	3.07	3.10	3.10	3.07	3.03	2.96	2.87	2.76	2.64	2.49	2.34	2.23	2.00	1.83
294.00	2.04	2.19	2.33	2.44	2.57	2.67	2.76	2.82	2.86	2.89	2.89	2.87	2.83	2.77	2.69	2.60	2.50	2.37	2.24	2.15	1.95	1.81
324.00	1.95	2.08	2.20	2.30	2.41	2.49	2.56	2.62	2.66	2.68	2.68	2.66	2.63	2.58	2.52	2.44	2.35	2.25	2.13	2.06	1.89	1.76
355.00	1.86	1.96	2.07	2.15	2.24	2.31	2.37	2.42	2.45	2.47	2.47	2.46	2.44	2.40	2.34	2.28	2.20	2.11	2.02	1.95	1.81	1.70
386.00	1.76	1.85	1.93	2.00	2.08	2.14	2.20	2.23	2.26	2.28	2.28	2.27	2.25	2.22	2.17	2.12	2.05	1.98	1.90	1.85	1.72	1.63
417.50	1.66	1.73	1.81	1.86	1.93	1.98	2.03	2.06	2.08	2.10	2.10	2.09	2.07	2.05	2.01	1.96	1.91	1.85	1.78	1.74	1.63	1.55
463.00	1.51	1.58	1.63	1.68	1.73	1.77	1.80	1.83	1.85	1.86	1.86	1.86	1.84	1.82	1.79	1.76	1.72	1.67	1.62	1.58	1.50	1.43
542.00	1.29	1.33	1.37	1.40	1.43	1.46	1.48	1.50	1.51	1.52	1.52	1.51	1.51	1.49	1.48	1.45	1.43	1.39	1.36	1.34	1.28	1.24
642.00	1.05	1.07	1.09	1.11	1.13	1.15	1.16	1.17	1.18	1.19	1.19	1.19	1.18	1.17	1.16	1.15	1.13	1.11	1.09	1.08	1.04	1.02
742.00	0.85	0.87	0.89	0.90	0.91	0.92	0.93	0.94	0.94	0.94	0.95	0.94	0.94	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.86	0.84
842.00	0.71	0.72	0.73	0.73	0.74	0.75	0.76	0.76	0.76	0.76	0.77	0.76	0.76	0.76	0.76	0.75	0.74	0.74	0.73	0.72	0.71	0.70
942.00	0.59	0.60	0.60	0.61	0.61	0.62	0.62	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.62	0.62	0.62	0.61	0.60	0.60	0.59	0.58

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
12	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
13	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.08**	**0.08**	**0.09**	**0.09**	**0.10**	**0.10**	**0.10**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.10**	**0.10**	**0.10**	**0.10**	**0.09**	**0.09**	**0.08**	**0.08**	**0.07**	**0.07**

Settlement Calculation, Best Estimated Rock Modulus, Line 14 (West Boundary)

Settlement Calculation, Best Estimated Rock Modulus, Line 14 (West Boundary)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-145.6	-238.7	**0.08**	**2**	-129.8	-238.7	**0.08**
3	-114.1	-238.7	**0.09**	**4**	-100.4	-238.7	**0.09**
5	-82.6	-238.7	**0.10**	**6**	-66.8	-238.7	**0.10**
7	-51.1	-238.7	**0.10**	**8**	-35.3	-238.7	**0.11**
9	-19.6	-238.7	**0.11**	**10**	0.0	-238.7	**0.11**
11	14.2	-238.7	**0.11**	**12**	27.7	-238.7	**0.11**
13	43.4	-238.7	**0.10**	**14**	59.2	-238.7	**0.10**
15	74.9	-238.7	**0.10**	**16**	90.7	-238.7	**0.10**
17	106.0	-238.7	**0.09**	**18**	122.2	-238.7	**0.09**
19	137.9	-238.7	**0.08**	**20**	148.0	-238.7	**0.08**
21	169.4	-238.7	**0.07**	**22**	185.2	-238.7	**0.07**

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, LBRM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 1 (North Boundary)

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	171.0	2	-145.6	151.5
3	-145.6	138.0	4	-145.6	105.0
5	-145.6	93.0	6	-145.6	73.5
7	-145.6	54.0	8	-145.6	34.4
9	-145.6	14.9	10	-145.6	0.0
11	-145.6	-24.1	12	-145.6	-43.6
13	-145.6	-63.1	14	-145.6	-82.6
15	-145.6	-102.1	16	-145.6	-110.7
17	-145.6	-141.1	18	-145.6	-160.6
19	-145.6	-174.7	20	-145.6	-199.7
21	-145.6	-219.2	22	-145.6	-238.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	91508	2	15.00	18.00	91508
3	28.00	8.00	11650	4	36.00	8.00	11650
5	50.00	20.00	139212	6	70.00	20.00	139212
7	92.50	25.00	139212	8	107.00	4.00	11650
9	120.50	23.00	139212	10	149.00	34.00	139212
11	183.00	34.00	139212	12	214.50	29.00	44754
13	239.00	20.00	91866	14	264.00	30.00	91866
15	294.00	30.00	91866	16	324.00	30.00	75174
17	355.00	32.00	75174	18	386.00	30.00	90209
19	417.50	33.00	90209	20	463.00	58.00	200298
21	542.00	100.00	200298	22	642.00	100.00	200298
23	742.00	100.00	200298	24	842.00	100.00	200298
25	942.00	100.00	200298				

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 1 (North Boundary)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Depth (FT)	Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	0.00	0.01	0.03	3.27	6.12	6.50	6.53	6.53	6.54	6.54	6.54	6.54	6.53	6.52	6.33	5.65	4.77	4.76	4.75	4.74	4.65	2.38
70.00	0.10	0.24	0.50	3.27	4.78	5.99	6.34	6.45	6.48	6.50	6.50	6.49	6.45	6.33	5.91	5.60	4.84	4.71	4.65	4.46	3.91	2.35
92.50	0.38	0.73	1.16	3.26	4.18	5.30	5.90	6.18	6.31	6.35	6.37	6.34	6.25	6.04	5.68	5.47	4.84	4.58	4.41	3.97	3.31	2.30
107.00	0.61	1.03	1.49	3.26	3.98	4.96	5.59	5.94	6.13	6.20	6.24	6.20	6.08	5.87	5.54	5.37	4.78	4.46	4.24	3.72	3.09	2.27
120.50	0.82	1.27	1.72	3.24	3.85	4.71	5.32	5.71	5.94	6.03	6.08	6.04	5.91	5.70	5.40	5.25	4.69	4.35	4.10	3.54	2.96	2.26
149.00	1.19	1.65	2.04	3.20	3.65	4.30	4.84	5.23	5.48	5.60	5.68	5.65	5.54	5.35	5.09	4.97	4.46	4.10	3.83	3.27	2.78	2.24
183.00	1.51	1.92	2.24	3.12	3.44	3.94	4.36	4.70	4.94	5.07	5.16	5.15	5.06	4.91	4.69	4.59	4.14	3.81	3.55	3.06	2.65	2.23
214.50	1.68	2.04	2.31	3.00	3.26	3.64	3.99	4.27	4.48	4.59	4.68	4.68	4.61	4.49	4.31	4.22	3.84	3.55	3.32	2.90	2.55	2.20
239.00	1.76	2.08	2.31	2.90	3.11	3.43	3.72	3.96	4.14	4.24	4.33	4.33	4.28	4.17	4.02	3.94	3.60	3.35	3.15	2.77	2.47	2.16
264.00	1.80	2.08	2.28	2.77	2.95	3.22	3.46	3.67	3.82	3.91	3.99	4.00	3.95	3.86	3.73	3.67	3.37	3.15	2.97	2.64	2.38	2.11
294.00	1.80	2.04	2.21	2.62	2.76	2.98	3.18	3.34	3.47	3.55	3.61	3.62	3.59	3.52	3.41	3.35	3.11	2.92	2.77	2.49	2.26	2.04
324.00	1.77	1.97	2.12	2.46	2.58	2.76	2.92	3.05	3.16	3.22	3.28	3.28	3.26	3.20	3.11	3.06	2.86	2.70	2.57	2.34	2.15	1.95
355.00	1.72	1.89	2.01	2.29	2.39	2.54	2.67	2.78	2.87	2.92	2.96	2.97	2.95	2.90	2.83	2.79	2.62	2.48	2.38	2.18	2.02	1.86
386.00	1.65	1.80	1.90	2.13	2.21	2.33	2.44	2.53	2.60	2.64	2.68	2.69	2.67	2.63	2.57	2.54	2.40	2.29	2.20	2.04	1.90	1.76
417.50	1.57	1.70	1.78	1.98	2.04	2.14	2.23	2.30	2.36	2.40	2.43	2.43	2.42	2.39	2.34	2.31	2.19	2.10	2.03	1.89	1.78	1.66
463.00	1.45	1.55	1.62	1.77	1.82	1.90	1.96	2.02	2.06	2.09	2.11	2.12	2.10	2.08	2.04	2.02	1.93	1.86	1.81	1.70	1.61	1.51
542.00	1.25	1.32	1.36	1.46	1.49	1.54	1.58	1.62	1.65	1.66	1.68	1.68	1.67	1.66	1.63	1.62	1.56	1.52	1.48	1.41	1.35	1.29
642.00	1.03	1.07	1.09	1.15	1.17	1.20	1.23	1.25	1.26	1.27	1.28	1.28	1.28	1.27	1.26	1.25	1.21	1.19	1.17	1.12	1.08	1.05
742.00	0.84	0.87	0.89	0.92	0.94	0.95	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.96	0.94	0.93	0.90	0.88	0.85
842.00	0.70	0.72	0.73	0.75	0.76	0.77	0.78	0.79	0.80	0.80	0.80	0.80	0.80	0.80	0.79	0.79	0.78	0.76	0.76	0.74	0.72	0.71
942.00	0.58	0.60	0.60	0.62	0.63	0.63	0.64	0.65	0.65	0.65	0.65	0.66	0.65	0.65	0.65	0.65	0.64	0.63	0.62	0.61	0.60	0.59

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 1 (North Boundary)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
6	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
7	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
8	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
9	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
10	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
11	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02
13	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
23	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.10**	**0.11**	**0.12**	**0.17**	**0.19**	**0.21**	**0.23**	**0.24**	**0.24**	**0.25**	**0.25**	**0.25**	**0.25**	**0.24**	**0.23**	**0.23**	**0.21**	**0.20**	**0.19**	**0.17**	**0.15**	**0.13**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 1 (North Boundary)

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 1 (North Boundary)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-145.6	171.0	**0.10**	**2**	-145.6	151.5	**0.11**
3	-145.6	138.0	**0.12**	**4**	-145.6	105.0	**0.17**
5	-145.6	93.0	**0.19**	**6**	-145.6	73.5	**0.21**
7	-145.6	54.0	**0.23**	**8**	-145.6	34.4	**0.24**
9	-145.6	14.9	**0.24**	**10**	-145.6	0.0	**0.25**
11	-145.6	-24.1	**0.25**	**12**	-145.6	-43.6	**0.25**
13	-145.6	-63.1	**0.25**	**14**	-145.6	-82.6	**0.24**
15	-145.6	-102.1	**0.23**	**16**	-145.6	-110.7	**0.23**
17	-145.6	-141.1	**0.21**	**18**	-145.6	-160.6	**0.20**
19	-145.6	-174.7	**0.19**	**20**	-145.6	-199.7	**0.17**
21	-145.6	-219.2	**0.15**	**22**	-145.6	-238.7	**0.13**

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, LBRM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 2 (45.18' South)

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-100.4	171.0	2	-100.4	151.5
3	-100.4	138.0	4	-100.4	105.0
5	-100.4	93.0	6	-100.4	73.5
7	-100.4	54.0	8	-100.4	34.4
9	-100.4	14.9	10	-100.4	0.0
11	-100.4	-24.1	12	-100.4	-43.6
13	-100.4	-63.1	14	-100.4	-82.6
15	-100.4	-102.1	16	-100.4	-110.7
17	-100.4	-141.1	18	-100.4	-160.6
19	-100.4	-174.7	20	-100.4	-199.7
21	-100.4	-219.2	22	-100.4	-238.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	91508	2	15.00	18.00	91508
3	28.00	8.00	11650	4	36.00	8.00	11650
5	50.00	20.00	139212	6	70.00	20.00	139212
7	92.50	25.00	139212	8	107.00	4.00	11650
9	120.50	23.00	139212	10	149.00	34.00	139212
11	183.00	34.00	139212	12	214.50	29.00	44754
13	239.00	20.00	91866	14	264.00	30.00	91866
15	294.00	30.00	91866	16	324.00	30.00	75174
17	355.00	32.00	75174	18	386.00	30.00	90209
19	417.50	33.00	90209	20	463.00	58.00	200298
21	542.00	100.00	200298	22	642.00	100.00	200298
23	742.00	100.00	200298	24	842.00	100.00	200298
25	942.00	100.00	200298				

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 2 (45.18' South)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	0.01	0.02	0.06	6.52	12.22	12.98	13.03	13.04	13.05	13.05	13.05	13.05	13.04	13.01	12.53	10.84	8.67	8.64	8.64	8.62	8.46	4.32
70.00	0.17	0.42	0.89	6.28	9.24	11.58	12.22	12.41	12.48	12.50	12.50	12.48	12.40	12.12	11.15	10.40	8.60	8.33	8.22	7.89	6.93	4.15
92.50	0.61	1.19	1.96	5.79	7.47	9.50	10.54	11.02	11.22	11.29	11.32	11.25	11.07	10.66	9.88	9.45	8.13	7.64	7.35	6.64	5.53	3.80
107.00	0.94	1.63	2.40	5.48	6.75	8.44	9.50	10.07	10.36	10.47	10.51	10.43	10.22	9.81	9.16	8.83	7.71	7.16	6.79	5.96	4.94	3.60
120.50	1.23	1.95	2.68	5.23	6.24	7.66	8.66	9.27	9.61	9.75	9.81	9.72	9.51	9.12	8.57	8.29	7.30	6.74	6.33	5.46	4.54	3.44
149.00	1.71	2.40	3.00	4.79	5.47	6.48	7.29	7.86	8.23	8.40	8.50	8.43	8.24	7.93	7.52	7.31	6.50	5.96	5.55	4.73	3.99	3.19
183.00	2.06	2.64	3.10	4.36	4.83	5.53	6.14	6.61	6.94	7.10	7.22	7.18	7.04	6.81	6.50	6.34	5.69	5.21	4.85	4.16	3.58	2.99
214.50	2.21	2.69	3.06	4.01	4.35	4.88	5.34	5.71	5.99	6.14	6.25	6.23	6.13	5.95	5.71	5.58	5.04	4.65	4.34	3.77	3.30	2.83
239.00	2.25	2.67	2.97	3.75	4.03	4.46	4.83	5.14	5.38	5.50	5.61	5.60	5.52	5.38	5.17	5.06	4.61	4.27	4.00	3.51	3.11	2.71
264.00	2.25	2.60	2.86	3.50	3.73	4.07	4.38	4.64	4.84	4.95	5.04	5.04	4.98	4.86	4.68	4.59	4.21	3.92	3.69	3.27	2.93	2.59
294.00	2.19	2.49	2.70	3.22	3.40	3.67	3.92	4.12	4.28	4.37	4.45	4.45	4.40	4.31	4.17	4.10	3.78	3.54	3.36	3.01	2.73	2.44
324.00	2.11	2.36	2.53	2.95	3.10	3.32	3.51	3.68	3.80	3.88	3.94	3.94	3.91	3.83	3.72	3.66	3.40	3.21	3.06	2.77	2.53	2.30
355.00	2.01	2.22	2.36	2.70	2.81	2.99	3.15	3.28	3.38	3.44	3.49	3.50	3.47	3.41	3.32	3.27	3.06	2.90	2.78	2.54	2.34	2.15
386.00	1.90	2.07	2.19	2.47	2.56	2.70	2.83	2.93	3.02	3.06	3.11	3.11	3.09	3.04	2.97	2.93	2.76	2.63	2.53	2.33	2.17	2.00
417.50	1.78	1.93	2.02	2.25	2.33	2.44	2.55	2.63	2.70	2.74	2.77	2.78	2.76	2.72	2.66	2.63	2.49	2.38	2.30	2.14	2.00	1.86
463.00	1.62	1.73	1.81	1.98	2.04	2.12	2.20	2.26	2.31	2.34	2.37	2.37	2.36	2.33	2.28	2.26	2.16	2.08	2.01	1.89	1.78	1.68
542.00	1.36	1.43	1.48	1.59	1.63	1.68	1.73	1.77	1.80	1.82	1.83	1.84	1.83	1.81	1.78	1.77	1.70	1.65	1.61	1.53	1.47	1.40
642.00	1.09	1.14	1.17	1.23	1.25	1.29	1.31	1.34	1.35	1.36	1.37	1.37	1.37	1.36	1.34	1.33	1.30	1.27	1.24	1.20	1.16	1.11
742.00	0.89	0.91	0.93	0.97	0.99	1.01	1.02	1.04	1.05	1.05	1.06	1.06	1.06	1.05	1.04	1.04	1.01	0.99	0.98	0.95	0.92	0.90
842.00	0.73	0.75	0.76	0.78	0.79	0.80	0.81	0.82	0.83	0.83	0.84	0.84	0.84	0.83	0.83	0.82	0.81	0.80	0.79	0.77	0.75	0.73
942.00	0.60	0.62	0.62	0.64	0.65	0.66	0.66	0.67	0.67	0.68	0.68	0.68	0.68	0.67	0.67	0.67	0.66	0.65	0.64	0.63	0.62	0.61

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
6	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
7	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
8	0.00	0.01	0.01	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.01
9	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
10	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
11	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
12	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
23	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.12**	**0.14**	**0.15**	**0.23**	**0.26**	**0.29**	**0.31**	**0.33**	**0.34**	**0.34**	**0.35**	**0.35**	**0.34**	**0.33**	**0.32**	**0.31**	**0.28**	**0.26**	**0.25**	**0.23**	**0.20**	**0.17**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 2 (45.18' South)

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 2 (45.18' South)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-100.4	171.0	**0.12**	**2**	-100.4	151.5	**0.14**
3	-100.4	138.0	**0.15**	**4**	-100.4	105.0	**0.23**
5	-100.4	93.0	**0.26**	**6**	-100.4	73.5	**0.29**
7	-100.4	54.0	**0.31**	**8**	-100.4	34.4	**0.33**
9	-100.4	14.9	**0.34**	**10**	-100.4	0.0	**0.34**
11	-100.4	-24.1	**0.35**	**12**	-100.4	-43.6	**0.35**
13	-100.4	-63.1	**0.34**	**14**	-100.4	-82.6	**0.33**
15	-100.4	-102.1	**0.32**	**16**	-100.4	-110.7	**0.31**
17	-100.4	-141.1	**0.28**	**18**	-100.4	-160.6	**0.26**
19	-100.4	-174.7	**0.25**	**20**	-100.4	-199.7	**0.23**
21	-100.4	-219.2	**0.20**	**22**	-100.4	-238.7	**0.17**

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, LBRM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 3 (145.58' South)

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	0.0	171.0	2	0.0	151.5
3	0.0	138.0	4	0.0	105.0
5	0.0	93.0	6	0.0	73.5
7	0.0	54.0	8	0.0	34.4
9	0.0	14.9	10	0.0	0.0
11	0.0	-24.1	12	0.0	-43.6
13	0.0	-63.1	14	0.0	-82.6
15	0.0	-102.1	16	0.0	-110.7
17	0.0	-141.1	18	0.0	-160.6
19	0.0	-174.7	20	0.0	-199.7
21	0.0	-219.2	22	0.0	-238.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	91508	2	15.00	18.00	91508
3	28.00	8.00	11650	4	36.00	8.00	11650
5	50.00	20.00	139212	6	70.00	20.00	139212
7	92.50	25.00	139212	8	107.00	4.00	11650
9	120.50	23.00	139212	10	149.00	34.00	139212
11	183.00	34.00	139212	12	214.50	29.00	44754
13	239.00	20.00	91866	14	264.00	30.00	91866
15	294.00	30.00	91866	16	324.00	30.00	75174
17	355.00	32.00	75174	18	386.00	30.00	90209
19	417.50	33.00	90209	20	463.00	58.00	200298
21	542.00	100.00	200298	22	642.00	100.00	200298
23	742.00	100.00	200298	24	842.00	100.00	200298
25	942.00	100.00	200298				

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 3 (145.58' South)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	0.17	0.32	0.38	6.70	12.30	13.01	13.06	13.07	13.07	13.07	13.07	13.07	13.07	13.03	12.46	10.44	7.84	7.81	7.80	7.78	7.63	3.90
70.00	1.01	1.75	2.34	7.33	10.02	12.14	12.72	12.89	12.95	12.97	12.97	12.94	12.84	12.49	11.30	10.39	8.20	7.86	7.74	7.39	6.47	3.90
92.50	1.75	2.78	3.72	7.46	9.02	10.89	11.87	12.32	12.52	12.58	12.59	12.49	12.25	11.71	10.72	10.17	8.50	7.88	7.53	6.74	5.61	3.89
107.00	2.15	3.23	4.19	7.36	8.59	10.20	11.23	11.79	12.07	12.17	12.19	12.06	11.77	11.22	10.37	9.94	8.48	7.78	7.33	6.38	5.28	3.88
120.50	2.45	3.53	4.45	7.19	8.21	9.63	10.62	11.23	11.57	11.70	11.73	11.59	11.29	10.76	10.02	9.65	8.35	7.62	7.11	6.09	5.06	3.86
149.00	2.89	3.86	4.62	6.70	7.45	8.53	9.38	9.99	10.37	10.54	10.60	10.47	10.19	9.76	9.19	8.90	7.83	7.12	6.60	5.59	4.71	3.78
183.00	3.11	3.90	4.50	6.03	6.57	7.37	8.04	8.56	8.91	9.08	9.16	9.08	8.87	8.53	8.10	7.88	7.01	6.40	5.94	5.06	4.34	3.62
214.50	3.12	3.76	4.23	5.40	5.81	6.43	6.96	7.38	7.68	7.83	7.92	7.87	7.71	7.45	7.11	6.94	6.24	5.72	5.33	4.60	4.02	3.44
239.00	3.05	3.59	3.98	4.94	5.28	5.78	6.22	6.57	6.83	6.96	7.05	7.01	6.89	6.68	6.40	6.26	5.66	5.23	4.89	4.27	3.77	3.27
264.00	2.94	3.40	3.72	4.51	4.78	5.19	5.55	5.84	6.06	6.18	6.26	6.24	6.14	5.97	5.74	5.62	5.12	4.75	4.47	3.94	3.52	3.10
294.00	2.78	3.15	3.41	4.03	4.25	4.57	4.86	5.09	5.27	5.36	5.44	5.42	5.35	5.22	5.04	4.94	4.54	4.24	4.01	3.58	3.23	2.89
324.00	2.60	2.90	3.11	3.61	3.79	4.04	4.27	4.46	4.60	4.68	4.74	4.73	4.68	4.57	4.43	4.35	4.03	3.79	3.60	3.25	2.96	2.68
355.00	2.41	2.66	2.83	3.23	3.37	3.57	3.75	3.90	4.02	4.08	4.13	4.13	4.09	4.01	3.89	3.83	3.57	3.38	3.23	2.94	2.71	2.47
386.00	2.23	2.44	2.57	2.90	3.01	3.17	3.32	3.44	3.53	3.58	3.62	3.62	3.59	3.52	3.43	3.39	3.18	3.02	2.90	2.67	2.47	2.28
417.50	2.06	2.23	2.34	2.60	2.69	2.82	2.94	3.03	3.11	3.15	3.18	3.18	3.16	3.11	3.04	3.00	2.83	2.71	2.61	2.42	2.26	2.10
463.00	1.83	1.96	2.04	2.24	2.31	2.40	2.49	2.56	2.61	2.64	2.67	2.67	2.65	2.62	2.56	2.54	2.41	2.32	2.25	2.10	1.98	1.86
542.00	1.50	1.58	1.63	1.76	1.80	1.86	1.91	1.95	1.98	2.00	2.02	2.02	2.01	1.99	1.96	1.94	1.86	1.81	1.76	1.67	1.60	1.52
642.00	1.18	1.22	1.26	1.33	1.35	1.38	1.41	1.44	1.46	1.47	1.47	1.48	1.47	1.46	1.44	1.43	1.39	1.36	1.33	1.28	1.23	1.19
742.00	0.94	0.97	0.99	1.03	1.04	1.06	1.08	1.10	1.11	1.11	1.12	1.12	1.12	1.11	1.10	1.09	1.07	1.05	1.03	1.00	0.97	0.94
842.00	0.76	0.78	0.79	0.82	0.83	0.84	0.85	0.86	0.87	0.87	0.88	0.88	0.87	0.87	0.86	0.86	0.84	0.83	0.82	0.80	0.78	0.76
942.00	0.63	0.64	0.65	0.67	0.67	0.68	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.69	0.68	0.67	0.67	0.65	0.64	0.63

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 3 (145.58' South)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
6	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
7	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
8	0.01	0.01	0.02	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.01
9	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
10	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
11	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
12	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.02
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
17	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
23	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.16**	**0.18**	**0.21**	**0.28**	**0.32**	**0.35**	**0.37**	**0.39**	**0.40**	**0.40**	**0.41**	**0.41**	**0.40**	**0.39**	**0.37**	**0.36**	**0.32**	**0.30**	**0.28**	**0.25**	**0.23**	**0.19**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 3 (145.58' South)

SUMMARY OF SETTLEMENT							
Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	0.0	171.0	0.16	2	0.0	151.5	0.18
3	0.0	138.0	0.21	4	0.0	105.0	0.28
5	0.0	93.0	0.32	6	0.0	73.5	0.35
7	0.0	54.0	0.37	8	0.0	34.4	0.39
9	0.0	14.9	0.40	10	0.0	0.0	0.40
11	0.0	-24.1	0.41	12	0.0	-43.6	0.41
13	0.0	-63.1	0.40	14	0.0	-82.6	0.39
15	0.0	-102.1	0.37	16	0.0	-110.7	0.36
17	0.0	-141.1	0.32	18	0.0	-160.6	0.30
19	0.0	-174.7	0.28	20	0.0	-199.7	0.25
21	0.0	-219.2	0.23	22	0.0	-238.7	0.19

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 3 (145.58' South)

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, LBRM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 4 (159.747' South)

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	14.2	171.0	2	14.2	151.5
3	14.2	138.0	4	14.2	105.0
5	14.2	93.0	6	14.2	73.5
7	14.2	54.0	8	14.2	34.4
9	14.2	14.9	10	14.2	0.0
11	14.2	-24.1	12	14.2	-43.6
13	14.2	-63.1	14	14.2	-82.6
15	14.2	-102.1	16	14.2	-110.7
17	14.2	-141.1	18	14.2	-160.6
19	14.2	-174.7	20	14.2	-199.7
21	14.2	-219.2	22	14.2	-238.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	91508	2	15.00	18.00	91508
3	28.00	8.00	11650	4	36.00	8.00	11650
5	50.00	20.00	139212	6	70.00	20.00	139212
7	92.50	25.00	139212	8	107.00	4.00	11650
9	120.50	23.00	139212	10	149.00	34.00	139212
11	183.00	34.00	139212	12	214.50	29.00	44754
13	239.00	20.00	91866	14	264.00	30.00	91866
15	294.00	30.00	91866	16	324.00	30.00	75174
17	355.00	32.00	75174	18	386.00	30.00	90209
19	417.50	33.00	90209	20	463.00	58.00	200298
21	542.00	100.00	200298	22	642.00	100.00	200298
23	742.00	100.00	200298	24	842.00	100.00	200298
25	942.00	100.00	200298				

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 4 (159.747' South)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	1.84	3.60	3.69	8.36	12.47	13.02	13.06	13.07	13.07	13.07	13.07	13.07	13.07	13.03	12.46	10.44	7.83	7.81	7.80	7.78	7.63	3.90
70.00	1.96	3.37	4.08	8.28	10.48	12.24	12.74	12.90	12.95	12.97	12.97	12.93	12.83	12.48	11.29	10.38	8.19	7.86	7.73	7.39	6.47	3.90
92.50	2.31	3.58	4.58	8.01	9.39	11.05	11.92	12.33	12.52	12.58	12.58	12.48	12.23	11.69	10.70	10.16	8.48	7.86	7.51	6.73	5.60	3.88
107.00	2.56	3.78	4.77	7.76	8.88	10.36	11.29	11.81	12.07	12.16	12.17	12.04	11.75	11.20	10.35	9.92	8.46	7.76	7.31	6.36	5.27	3.86
120.50	2.77	3.93	4.87	7.50	8.45	9.76	10.69	11.26	11.57	11.69	11.71	11.57	11.26	10.74	10.00	9.63	8.32	7.59	7.09	6.07	5.04	3.84
149.00	3.09	4.09	4.86	6.89	7.60	8.64	9.45	10.02	10.38	10.53	10.58	10.45	10.17	9.73	9.16	8.88	7.80	7.09	6.57	5.56	4.68	3.76
183.00	3.23	4.03	4.63	6.14	6.67	7.45	8.10	8.59	8.93	9.09	9.16	9.07	8.85	8.52	8.08	7.86	6.99	6.38	5.92	5.04	4.33	3.61
214.50	3.20	3.84	4.31	5.47	5.88	6.48	7.00	7.41	7.70	7.84	7.92	7.87	7.70	7.45	7.10	6.93	6.22	5.71	5.32	4.59	4.01	3.43
239.00	3.11	3.65	4.04	5.00	5.33	5.82	6.25	6.60	6.85	6.97	7.06	7.02	6.89	6.68	6.40	6.25	5.65	5.22	4.88	4.26	3.76	3.27
264.00	2.98	3.44	3.76	4.55	4.82	5.23	5.58	5.87	6.08	6.19	6.27	6.24	6.14	5.97	5.74	5.62	5.12	4.75	4.47	3.94	3.51	3.10
294.00	2.81	3.18	3.44	4.06	4.28	4.60	4.88	5.11	5.29	5.38	5.45	5.43	5.36	5.22	5.04	4.94	4.54	4.24	4.01	3.58	3.23	2.89
324.00	2.62	2.92	3.14	3.64	3.81	4.06	4.29	4.47	4.61	4.69	4.75	4.74	4.68	4.58	4.43	4.36	4.03	3.79	3.60	3.25	2.96	2.68
355.00	2.43	2.68	2.85	3.25	3.39	3.59	3.77	3.92	4.03	4.09	4.14	4.13	4.09	4.01	3.90	3.84	3.58	3.38	3.23	2.94	2.71	2.47
386.00	2.25	2.45	2.59	2.91	3.02	3.18	3.33	3.45	3.54	3.59	3.63	3.63	3.59	3.53	3.44	3.39	3.18	3.02	2.90	2.67	2.48	2.28
417.50	2.07	2.24	2.35	2.61	2.70	2.83	2.95	3.04	3.12	3.16	3.19	3.19	3.16	3.11	3.04	3.00	2.84	2.71	2.61	2.42	2.26	2.10
463.00	1.84	1.97	2.05	2.25	2.31	2.41	2.50	2.57	2.62	2.65	2.67	2.67	2.66	2.62	2.57	2.54	2.42	2.32	2.25	2.10	1.98	1.86
542.00	1.50	1.58	1.64	1.76	1.80	1.86	1.91	1.95	1.99	2.00	2.02	2.02	2.01	1.99	1.96	1.94	1.87	1.81	1.76	1.67	1.60	1.52
642.00	1.18	1.23	1.26	1.33	1.35	1.39	1.41	1.44	1.46	1.47	1.48	1.48	1.47	1.46	1.44	1.43	1.39	1.36	1.33	1.28	1.23	1.19
742.00	0.94	0.97	0.99	1.03	1.05	1.07	1.08	1.10	1.11	1.11	1.12	1.12	1.12	1.11	1.10	1.09	1.07	1.05	1.03	1.00	0.97	0.95
842.00	0.76	0.78	0.79	0.82	0.83	0.84	0.85	0.86	0.87	0.87	0.88	0.88	0.87	0.87	0.86	0.86	0.84	0.83	0.82	0.80	0.78	0.77
942.00	0.63	0.64	0.65	0.67	0.67	0.68	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.69	0.68	0.67	0.67	0.65	0.64	0.63

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 4 (159.747' South)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
6	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
7	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
8	0.01	0.01	0.02	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.01
9	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
10	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
11	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
12	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.02
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
17	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
23	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.16**	**0.20**	**0.22**	**0.29**	**0.32**	**0.35**	**0.37**	**0.39**	**0.40**	**0.40**	**0.41**	**0.41**	**0.40**	**0.39**	**0.37**	**0.36**	**0.32**	**0.30**	**0.28**	**0.25**	**0.23**	**0.19**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 4 (159.747' South)

SUMMARY OF SETTLEMENT							
Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	14.2	171.0	**0.16**	**2**	14.2	151.5	**0.20**
3	14.2	138.0	**0.22**	**4**	14.2	105.0	**0.29**
5	14.2	93.0	**0.32**	**6**	14.2	73.5	**0.35**
7	14.2	54.0	**0.37**	**8**	14.2	34.4	**0.39**
9	14.2	14.9	**0.40**	**10**	14.2	0.0	**0.40**
11	14.2	-24.1	**0.41**	**12**	14.2	-43.6	**0.41**
13	14.2	-63.1	**0.40**	**14**	14.2	-82.6	**0.39**
15	14.2	-102.1	**0.37**	**16**	14.2	-110.7	**0.36**
17	14.2	-141.1	**0.32**	**18**	14.2	-160.6	**0.30**
19	14.2	-174.7	**0.28**	**20**	14.2	-199.7	**0.25**
21	14.2	-219.2	**0.23**	**22**	14.2	-238.7	**0.19**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 4 (159.747' South)

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, LBRM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 5 (251.58' South)

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES

ID	X	Y	ID	X	Y
1	106.0	171.0	2	106.0	151.5
3	106.0	138.0	4	106.0	105.0
5	106.0	93.0	6	106.0	73.5
7	106.0	54.0	8	106.0	34.4
9	106.0	14.9	10	106.0	0.0
11	106.0	-24.1	12	106.0	-43.6
13	106.0	-63.1	14	106.0	-82.6
15	106.0	-102.1	16	106.0	-110.7
17	106.0	-141.1	18	106.0	-160.6
19	106.0	-174.7	20	106.0	-199.7
21	106.0	-219.2	22	106.0	-238.7

LAYER COMPRESSIBILITY

LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	91508	2	15.00	18.00	91508
3	28.00	8.00	11650	4	36.00	8.00	11650
5	50.00	20.00	139212	6	70.00	20.00	139212
7	92.50	25.00	139212	8	107.00	4.00	11650
9	120.50	23.00	139212	10	149.00	34.00	139212
11	183.00	34.00	139212	12	214.50	29.00	44754
13	239.00	20.00	91866	14	264.00	30.00	91866
15	294.00	30.00	91866	16	324.00	30.00	75174
17	355.00	32.00	75174	18	386.00	30.00	90209
19	417.50	33.00	90209	20	463.00	58.00	200298
21	542.00	100.00	200298	22	642.00	100.00	200298
23	742.00	100.00	200298	24	842.00	100.00	200298
25	942.00	100.00	200298				

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 5 (251.58' South)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	3.66	7.16	7.30	9.30	11.04	11.28	11.30	11.30	11.30	11.30	11.30	11.30	11.29	11.26	10.75	8.94	6.61	6.58	6.58	6.56	6.44	3.29
70.00	3.66	6.14	6.98	9.10	10.05	10.82	11.05	11.12	11.14	11.15	11.14	11.11	11.02	10.72	9.66	8.85	6.91	6.62	6.51	6.23	5.45	3.28
92.50	3.65	5.40	6.40	8.49	9.17	9.95	10.36	10.56	10.65	10.67	10.65	10.57	10.35	9.89	9.03	8.56	7.10	6.58	6.28	5.63	4.68	3.24
107.00	3.62	5.09	6.02	7.99	8.59	9.34	9.81	10.07	10.19	10.23	10.21	10.09	9.84	9.37	8.64	8.27	7.03	6.44	6.07	5.28	4.38	3.21
120.50	3.58	4.84	5.68	7.51	8.06	8.77	9.26	9.56	9.72	9.77	9.75	9.61	9.35	8.90	8.28	7.96	6.87	6.26	5.85	5.01	4.16	3.16
149.00	3.45	4.40	5.06	6.56	7.02	7.66	8.14	8.47	8.67	8.74	8.73	8.60	8.35	7.98	7.50	7.27	6.38	5.80	5.37	4.55	3.83	3.07
183.00	3.26	3.97	4.47	5.63	6.00	6.53	6.96	7.27	7.48	7.56	7.57	7.47	7.28	6.99	6.62	6.44	5.73	5.22	4.84	4.13	3.55	2.96
214.50	3.07	3.63	4.02	4.93	5.24	5.67	6.04	6.31	6.50	6.59	6.62	6.55	6.39	6.17	5.88	5.73	5.15	4.72	4.40	3.80	3.32	2.85
239.00	2.93	3.39	3.72	4.48	4.74	5.11	5.42	5.67	5.84	5.92	5.96	5.90	5.78	5.60	5.35	5.23	4.73	4.36	4.09	3.57	3.16	2.75
264.00	2.78	3.17	3.44	4.08	4.29	4.61	4.88	5.09	5.24	5.31	5.35	5.32	5.22	5.07	4.86	4.76	4.34	4.02	3.78	3.34	2.99	2.64
294.00	2.60	2.92	3.14	3.66	3.83	4.09	4.31	4.49	4.61	4.68	4.72	4.69	4.62	4.50	4.34	4.25	3.91	3.65	3.45	3.08	2.79	2.50
324.00	2.42	2.69	2.87	3.29	3.43	3.64	3.82	3.97	4.08	4.13	4.17	4.16	4.10	4.00	3.87	3.80	3.52	3.31	3.15	2.84	2.60	2.35
355.00	2.25	2.47	2.62	2.96	3.08	3.25	3.40	3.52	3.61	3.65	3.69	3.67	3.63	3.56	3.45	3.40	3.17	3.00	2.86	2.61	2.41	2.20
386.00	2.09	2.27	2.39	2.67	2.77	2.91	3.03	3.13	3.20	3.24	3.27	3.26	3.23	3.17	3.08	3.04	2.85	2.71	2.60	2.40	2.23	2.05
417.50	1.93	2.08	2.18	2.41	2.49	2.61	2.71	2.79	2.85	2.88	2.90	2.90	2.87	2.83	2.76	2.72	2.57	2.46	2.37	2.20	2.06	1.91
463.00	1.73	1.84	1.92	2.10	2.16	2.24	2.32	2.38	2.42	2.45	2.47	2.47	2.45	2.41	2.36	2.34	2.22	2.14	2.07	1.94	1.83	1.72
542.00	1.43	1.50	1.55	1.66	1.70	1.76	1.80	1.84	1.87	1.89	1.90	1.90	1.89	1.87	1.84	1.82	1.75	1.70	1.65	1.57	1.50	1.43
642.00	1.13	1.18	1.21	1.27	1.29	1.33	1.35	1.37	1.39	1.40	1.41	1.41	1.40	1.39	1.37	1.37	1.33	1.29	1.27	1.22	1.18	1.13
742.00	0.91	0.94	0.96	1.00	1.01	1.03	1.05	1.06	1.07	1.08	1.08	1.08	1.08	1.07	1.06	1.05	1.03	1.01	1.00	0.97	0.94	0.91
842.00	0.74	0.76	0.77	0.80	0.81	0.82	0.83	0.84	0.84	0.85	0.85	0.85	0.85	0.85	0.84	0.84	0.82	0.81	0.80	0.78	0.76	0.74
942.00	0.61	0.63	0.63	0.65	0.66	0.67	0.67	0.68	0.68	0.68	0.69	0.69	0.69	0.68	0.68	0.68	0.67	0.66	0.65	0.64	0.63	0.62

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 5 (251.58' South)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
6	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
7	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
8	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01
9	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
10	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
11	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
12	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
23	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.17**	**0.21**	**0.23**	**0.28**	**0.30**	**0.32**	**0.33**	**0.34**	**0.35**	**0.35**	**0.35**	**0.35**	**0.34**	**0.33**	**0.32**	**0.30**	**0.27**	**0.25**	**0.24**	**0.22**	**0.19**	**0.16**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 5 (251.58' South)

SUMMARY OF SETTLEMENT							
Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	106.0	171.0	0.17	2	106.0	151.5	0.21
3	106.0	138.0	0.23	4	106.0	105.0	0.28
5	106.0	93.0	0.30	6	106.0	73.5	0.32
7	106.0	54.0	0.33	8	106.0	34.4	0.34
9	106.0	14.9	0.35	10	106.0	0.0	0.35
11	106.0	-24.1	0.35	12	106.0	-43.6	0.35
13	106.0	-63.1	0.34	14	106.0	-82.6	0.33
15	106.0	-102.1	0.32	16	106.0	-110.7	0.30
17	106.0	-141.1	0.27	18	106.0	-160.6	0.25
19	106.0	-174.7	0.24	20	106.0	-199.7	0.22
21	106.0	-219.2	0.19	22	106.0	-238.7	0.16

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 5 (251.58' South)

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, LBRM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 6 (293.58' South)

SUMMARY OF INPUT

Number of Loaded Areas= 9 **Number of Soil Layers=** 25 **Number of Settlement Points=** 22

Poisson's Ratio= 0.30 **Stress distribution code=** 1 **Depth of Grondwater Table=** 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	148.0	171.0	2	148.0	151.5
3	148.0	138.0	4	148.0	105.0
5	148.0	93.0	6	148.0	73.5
7	148.0	54.0	8	148.0	34.4
9	148.0	14.9	10	148.0	0.0
11	148.0	-24.1	12	148.0	-43.6
13	148.0	-63.1	14	148.0	-82.6
15	148.0	-102.1	16	148.0	-110.7
17	148.0	-141.1	18	148.0	-160.6
19	148.0	-174.7	20	148.0	-199.7
21	148.0	-219.2	22	148.0	-238.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	91508	2	15.00	18.00	91508
3	28.00	8.00	11650	4	36.00	8.00	11650
5	50.00	20.00	139212	6	70.00	20.00	139212
7	92.50	25.00	139212	8	107.00	4.00	11650
9	120.50	23.00	139212	10	149.00	34.00	139212
11	183.00	34.00	139212	12	214.50	29.00	44754
13	239.00	20.00	91866	14	264.00	30.00	91866
15	294.00	30.00	91866	16	324.00	30.00	75174
17	355.00	32.00	75174	18	386.00	30.00	90209
19	417.50	33.00	90209	20	463.00	58.00	200298
21	542.00	100.00	200298	22	642.00	100.00	200298
23	742.00	100.00	200298	24	842.00	100.00	200298
25	942.00	100.00	200298				

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 6 (293.58' South)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	3.65	7.14	7.27	8.25	9.10	9.21	9.22	9.23	9.23	9.23	9.23	9.23	9.22	9.20	8.81	7.45	5.69	5.67	5.67	5.65	5.55	2.83
70.00	3.47	5.83	6.55	7.78	8.27	8.66	8.78	8.82	8.84	8.84	8.84	8.82	8.75	8.53	7.74	7.14	5.70	5.48	5.40	5.18	4.54	2.72
92.50	3.21	4.72	5.52	6.91	7.31	7.76	8.00	8.12	8.17	8.18	8.17	8.10	7.94	7.60	6.98	6.63	5.57	5.18	4.96	4.46	3.71	2.56
107.00	3.08	4.29	5.02	6.39	6.77	7.23	7.51	7.68	7.76	7.78	7.75	7.67	7.48	7.13	6.61	6.33	5.43	4.99	4.71	4.11	3.41	2.50
120.50	3.00	4.01	4.67	5.96	6.33	6.79	7.10	7.29	7.39	7.43	7.40	7.30	7.10	6.77	6.31	6.08	5.28	4.83	4.51	3.87	3.22	2.45
149.00	2.86	3.62	4.13	5.23	5.56	6.00	6.33	6.55	6.68	6.73	6.71	6.61	6.42	6.14	5.78	5.61	4.94	4.50	4.17	3.54	2.99	2.40
183.00	2.73	3.30	3.69	4.57	4.85	5.24	5.55	5.77	5.92	5.97	5.97	5.89	5.73	5.51	5.23	5.09	4.53	4.14	3.84	3.29	2.83	2.37
214.50	2.61	3.06	3.37	4.09	4.32	4.65	4.93	5.13	5.27	5.33	5.35	5.29	5.16	4.98	4.75	4.64	4.17	3.83	3.57	3.10	2.71	2.33
239.00	2.52	2.89	3.16	3.77	3.97	4.26	4.50	4.69	4.82	4.88	4.90	4.86	4.75	4.60	4.40	4.31	3.90	3.60	3.38	2.96	2.62	2.29
264.00	2.41	2.74	2.96	3.48	3.65	3.90	4.12	4.28	4.40	4.46	4.48	4.45	4.37	4.24	4.07	3.99	3.63	3.38	3.18	2.82	2.52	2.23
294.00	2.29	2.55	2.74	3.17	3.31	3.52	3.70	3.84	3.95	4.00	4.03	4.00	3.94	3.83	3.70	3.63	3.33	3.12	2.95	2.65	2.40	2.15
324.00	2.16	2.38	2.54	2.89	3.01	3.19	3.34	3.46	3.55	3.59	3.62	3.60	3.55	3.47	3.36	3.30	3.06	2.88	2.74	2.48	2.27	2.06
355.00	2.03	2.21	2.34	2.64	2.73	2.88	3.00	3.11	3.18	3.22	3.24	3.23	3.19	3.13	3.04	2.99	2.79	2.64	2.53	2.31	2.13	1.95
386.00	1.90	2.05	2.16	2.41	2.49	2.61	2.71	2.80	2.86	2.89	2.92	2.91	2.88	2.82	2.75	2.71	2.55	2.42	2.33	2.15	2.00	1.85
417.50	1.77	1.90	1.99	2.20	2.26	2.36	2.45	2.52	2.57	2.60	2.62	2.62	2.59	2.55	2.49	2.46	2.32	2.22	2.14	1.99	1.86	1.74
463.00	1.60	1.71	1.77	1.93	1.98	2.06	2.13	2.18	2.22	2.24	2.26	2.26	2.24	2.21	2.16	2.14	2.04	1.96	1.90	1.78	1.68	1.58
542.00	1.34	1.41	1.46	1.56	1.59	1.64	1.68	1.72	1.75	1.76	1.77	1.77	1.76	1.74	1.71	1.70	1.63	1.58	1.54	1.47	1.40	1.34
642.00	1.08	1.12	1.15	1.21	1.23	1.26	1.29	1.31	1.32	1.33	1.34	1.34	1.33	1.32	1.30	1.30	1.26	1.23	1.21	1.16	1.12	1.08
742.00	0.88	0.90	0.92	0.96	0.97	0.99	1.01	1.02	1.03	1.03	1.04	1.04	1.03	1.03	1.02	1.01	0.99	0.97	0.96	0.93	0.90	0.88
842.00	0.72	0.74	0.75	0.77	0.78	0.79	0.80	0.81	0.82	0.82	0.82	0.82	0.82	0.82	0.81	0.81	0.79	0.78	0.77	0.75	0.74	0.72
942.00	0.60	0.61	0.62	0.64	0.64	0.65	0.66	0.66	0.67	0.67	0.67	0.67	0.67	0.67	0.66	0.66	0.65	0.64	0.64	0.62	0.61	0.60

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 6 (293.58' South)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
6	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
7	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
9	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
10	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
23	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.15**	**0.19**	**0.20**	**0.24**	**0.25**	**0.26**	**0.27**	**0.28**	**0.29**	**0.29**	**0.29**	**0.29**	**0.28**	**0.28**	**0.26**	**0.25**	**0.23**	**0.21**	**0.20**	**0.18**	**0.17**	**0.14**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 6 (293.58' South)

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 6 (293.58' South)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	148.0	171.0	**0.15**	**2**	148.0	151.5	**0.19**
3	148.0	138.0	**0.20**	**4**	148.0	105.0	**0.24**
5	148.0	93.0	**0.25**	**6**	148.0	73.5	**0.26**
7	148.0	54.0	**0.27**	**8**	148.0	34.4	**0.28**
9	148.0	14.9	**0.29**	**10**	148.0	0.0	**0.29**
11	148.0	-24.1	**0.29**	**12**	148.0	-43.6	**0.29**
13	148.0	-63.1	**0.28**	**14**	148.0	-82.6	**0.28**
15	148.0	-102.1	**0.26**	**16**	148.0	-110.7	**0.25**
17	148.0	-141.1	**0.23**	**18**	148.0	-160.6	**0.21**
19	148.0	-174.7	**0.20**	**20**	148.0	-199.7	**0.18**
21	148.0	-219.2	**0.17**	**22**	148.0	-238.7	**0.14**

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, LBRM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	185.2	171.0	2	185.2	151.5
3	185.2	138.0	4	185.2	105.0
5	185.2	93.0	6	185.2	73.5
7	185.2	54.0	8	185.2	34.4
9	185.2	14.9	10	185.2	0.0
11	185.2	-24.1	12	185.2	-43.6
13	185.2	-63.1	14	185.2	-82.6
15	185.2	-102.1	16	185.2	-110.7
17	185.2	-141.1	18	185.2	-160.6
19	185.2	-174.7	20	185.2	-199.7
21	185.2	-219.2	22	185.2	-238.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	91508	2	15.00	18.00	91508
3	28.00	8.00	11650	4	36.00	8.00	11650
5	50.00	20.00	139212	6	70.00	20.00	139212
7	92.50	25.00	139212	8	107.00	4.00	11650
9	120.50	23.00	139212	10	149.00	34.00	139212
11	183.00	34.00	139212	12	214.50	29.00	44754
13	239.00	20.00	91866	14	264.00	30.00	91866
15	294.00	30.00	91866	16	324.00	30.00	75174
17	355.00	32.00	75174	18	386.00	30.00	90209
19	417.50	33.00	90209	20	463.00	58.00	200298
21	542.00	100.00	200298	22	642.00	100.00	200298
23	742.00	100.00	200298	24	842.00	100.00	200298
25	942.00	100.00	200298				

Settlement Calculation,Lower Bound Estimated Rock Modulus, Line 7 (South Boundary)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	1.83	3.58	3.64	4.07	4.43	4.48	4.48	4.49	4.49	4.49	4.49	4.49	4.48	4.47	4.31	3.75	3.02	3.01	3.00	3.00	2.94	1.50
70.00	1.85	3.07	3.46	4.04	4.26	4.44	4.50	4.52	4.53	4.53	4.53	4.51	4.48	4.37	4.02	3.76	3.12	3.01	2.97	2.84	2.49	1.50
92.50	1.90	2.75	3.20	3.95	4.15	4.38	4.50	4.57	4.60	4.60	4.59	4.55	4.47	4.29	3.97	3.80	3.26	3.05	2.92	2.62	2.18	1.52
107.00	1.94	2.66	3.08	3.86	4.07	4.32	4.48	4.57	4.62	4.63	4.62	4.56	4.45	4.26	3.97	3.83	3.33	3.07	2.90	2.53	2.10	1.55
120.50	1.98	2.60	3.00	3.78	3.99	4.26	4.44	4.55	4.62	4.63	4.62	4.55	4.43	4.24	3.97	3.84	3.36	3.09	2.89	2.48	2.07	1.59
149.00	2.04	2.54	2.88	3.59	3.80	4.09	4.30	4.44	4.52	4.55	4.54	4.47	4.35	4.17	3.93	3.82	3.38	3.09	2.87	2.44	2.07	1.68
183.00	2.08	2.48	2.75	3.37	3.56	3.83	4.04	4.20	4.30	4.34	4.33	4.27	4.16	4.01	3.81	3.71	3.31	3.04	2.82	2.42	2.10	1.77
214.50	2.07	2.41	2.64	3.16	3.33	3.58	3.77	3.92	4.02	4.06	4.07	4.03	3.93	3.80	3.63	3.54	3.19	2.94	2.75	2.39	2.10	1.82
239.00	2.05	2.34	2.54	3.00	3.15	3.37	3.55	3.69	3.79	3.83	3.85	3.81	3.73	3.61	3.46	3.39	3.07	2.85	2.67	2.35	2.09	1.84
264.00	2.01	2.26	2.44	2.84	2.97	3.17	3.33	3.46	3.55	3.59	3.61	3.58	3.51	3.41	3.28	3.21	2.94	2.74	2.58	2.29	2.06	1.83
294.00	1.94	2.16	2.31	2.65	2.77	2.93	3.07	3.19	3.27	3.31	3.33	3.30	3.25	3.17	3.06	3.00	2.76	2.59	2.46	2.21	2.01	1.81
324.00	1.86	2.05	2.18	2.47	2.57	2.71	2.83	2.93	3.00	3.03	3.05	3.04	3.00	2.93	2.83	2.79	2.59	2.44	2.32	2.11	1.94	1.76
355.00	1.78	1.94	2.04	2.29	2.37	2.49	2.60	2.68	2.74	2.77	2.79	2.78	2.75	2.69	2.61	2.57	2.41	2.28	2.18	2.00	1.85	1.70
386.00	1.69	1.82	1.91	2.12	2.19	2.29	2.38	2.45	2.50	2.53	2.55	2.54	2.51	2.47	2.40	2.37	2.23	2.12	2.04	1.89	1.76	1.63
417.50	1.59	1.71	1.79	1.96	2.02	2.11	2.18	2.24	2.28	2.31	2.32	2.32	2.30	2.26	2.21	2.18	2.06	1.97	1.90	1.77	1.66	1.55
463.00	1.46	1.55	1.61	1.75	1.80	1.86	1.92	1.97	2.00	2.02	2.04	2.03	2.02	1.99	1.95	1.93	1.84	1.77	1.71	1.61	1.52	1.43
542.00	1.25	1.31	1.35	1.44	1.47	1.52	1.56	1.59	1.61	1.62	1.63	1.63	1.62	1.61	1.58	1.57	1.51	1.46	1.43	1.36	1.30	1.24
642.00	1.02	1.06	1.08	1.14	1.16	1.19	1.21	1.23	1.24	1.25	1.26	1.26	1.25	1.24	1.23	1.22	1.18	1.16	1.14	1.09	1.06	1.02
742.00	0.84	0.86	0.88	0.92	0.93	0.94	0.96	0.97	0.98	0.99	0.99	0.99	0.99	0.98	0.97	0.97	0.94	0.93	0.91	0.89	0.86	0.84
842.00	0.69	0.71	0.72	0.75	0.75	0.76	0.77	0.78	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.77	0.75	0.75	0.73	0.71	0.70
942.00	0.58	0.59	0.60	0.62	0.62	0.63	0.64	0.64	0.64	0.65	0.65	0.65	0.65	0.65	0.64	0.64	0.63	0.62	0.62	0.60	0.59	0.58

Settlement Calculation,Lower Bound Estimated Rock Modulus, Line 7 (South Boundary)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
8	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
9	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
12	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01
13	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
23	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.12**	**0.14**	**0.15**	**0.18**	**0.19**	**0.20**	**0.20**	**0.21**	**0.21**	**0.21**	**0.22**	**0.21**	**0.21**	**0.20**	**0.20**	**0.19**	**0.17**	**0.16**	**0.16**	**0.14**	**0.13**	**0.11**

Settlement Calculation,Lower Bound Estimated Rock Modulus, Line 7 (South Boundary)

Settlement Calculation,Lower Bound Estimated Rock Modulus, Line 7 (South Boundary)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	185.2	171.0	**0.12**	**2**	185.2	151.5	**0.14**
3	185.2	138.0	**0.15**	**4**	185.2	105.0	**0.18**
5	185.2	93.0	**0.19**	**6**	185.2	73.5	**0.20**
7	185.2	54.0	**0.20**	**8**	185.2	34.4	**0.21**
9	185.2	14.9	**0.21**	**10**	185.2	0.0	**0.21**
11	185.2	-24.1	**0.22**	**12**	185.2	-43.6	**0.21**
13	185.2	-63.1	**0.21**	**14**	185.2	-82.6	**0.20**
15	185.2	-102.1	**0.20**	**16**	185.2	-110.7	**0.19**
17	185.2	-141.1	**0.17**	**18**	185.2	-160.6	**0.16**
19	185.2	-174.7	**0.16**	**20**	185.2	-199.7	**0.14**
21	185.2	-219.2	**0.13**	**22**	185.2	-238.7	**0.11**

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, LBRM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 8 (East Boundary)

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	171.0	2	-129.8	171.0
3	-114.1	171.0	4	-100.4	171.0
5	-82.6	171.0	6	-66.8	171.0
7	-51.1	171.0	8	-35.3	171.0
9	-19.6	171.0	10	0.0	171.0
11	14.2	171.0	12	27.7	171.0
13	43.4	171.0	14	59.2	171.0
15	74.9	171.0	16	90.7	171.0
17	106.0	171.0	18	122.2	171.0
19	137.9	171.0	20	148.0	171.0
21	169.4	171.0	22	185.2	171.0

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	91508	2	15.00	18.00	91508
3	28.00	8.00	11650	4	36.00	8.00	11650
5	50.00	20.00	139212	6	70.00	20.00	139212
7	92.50	25.00	139212	8	107.00	4.00	11650
9	120.50	23.00	139212	10	149.00	34.00	139212
11	183.00	34.00	139212	12	214.50	29.00	44754
13	239.00	20.00	91866	14	264.00	30.00	91866
15	294.00	30.00	91866	16	324.00	30.00	75174
17	355.00	32.00	75174	18	386.00	30.00	90209
19	417.50	33.00	90209	20	463.00	58.00	200298
21	542.00	100.00	200298	22	642.00	100.00	200298
23	742.00	100.00	200298	24	842.00	100.00	200298
25	942.00	100.00	200298				

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 8 (East Boundary)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.17	1.84	3.48	3.64	3.65	3.66	3.66	3.66	3.66	3.65	3.65	3.53	1.83
70.00	0.10	0.13	0.15	0.17	0.19	0.21	0.23	0.29	0.43	1.01	1.96	2.88	3.42	3.60	3.66	3.67	3.66	3.63	3.56	3.47	2.89	1.85
92.50	0.38	0.47	0.55	0.61	0.68	0.74	0.83	0.96	1.20	1.75	2.31	2.84	3.29	3.55	3.66	3.69	3.65	3.56	3.38	3.21	2.57	1.90
107.00	0.61	0.73	0.84	0.94	1.05	1.15	1.27	1.43	1.68	2.15	2.56	2.95	3.31	3.55	3.66	3.68	3.62	3.49	3.28	3.08	2.49	1.94
120.50	0.82	0.96	1.11	1.23	1.37	1.50	1.64	1.82	2.06	2.45	2.77	3.07	3.36	3.55	3.64	3.65	3.58	3.43	3.19	3.00	2.45	1.98
149.00	1.19	1.38	1.56	1.71	1.90	2.07	2.24	2.42	2.62	2.89	3.09	3.26	3.43	3.54	3.57	3.54	3.45	3.28	3.04	2.86	2.41	2.04
183.00	1.51	1.70	1.90	2.06	2.26	2.44	2.61	2.77	2.93	3.11	3.23	3.33	3.40	3.44	3.43	3.37	3.26	3.09	2.89	2.73	2.37	2.08
214.50	1.68	1.87	2.06	2.21	2.41	2.57	2.72	2.86	2.99	3.12	3.20	3.26	3.29	3.29	3.26	3.18	3.07	2.92	2.74	2.61	2.31	2.07
239.00	1.76	1.94	2.11	2.25	2.43	2.58	2.72	2.84	2.95	3.05	3.11	3.15	3.16	3.15	3.11	3.03	2.93	2.79	2.63	2.52	2.25	2.05
264.00	1.80	1.96	2.11	2.25	2.41	2.54	2.66	2.77	2.86	2.94	2.98	3.01	3.01	2.99	2.94	2.87	2.78	2.65	2.51	2.41	2.18	2.01
294.00	1.80	1.94	2.08	2.19	2.33	2.45	2.55	2.64	2.71	2.78	2.81	2.82	2.82	2.79	2.75	2.68	2.60	2.49	2.37	2.29	2.09	1.94
324.00	1.77	1.89	2.01	2.11	2.23	2.33	2.41	2.49	2.55	2.60	2.62	2.63	2.62	2.60	2.56	2.50	2.42	2.33	2.23	2.16	1.99	1.86
355.00	1.72	1.82	1.93	2.01	2.11	2.19	2.26	2.32	2.37	2.41	2.43	2.43	2.43	2.40	2.37	2.31	2.25	2.17	2.09	2.03	1.89	1.78
386.00	1.65	1.74	1.83	1.90	1.98	2.05	2.11	2.16	2.20	2.23	2.25	2.25	2.24	2.22	2.19	2.14	2.09	2.02	1.95	1.90	1.78	1.69
417.50	1.57	1.65	1.72	1.78	1.86	1.91	1.96	2.00	2.03	2.06	2.07	2.07	2.06	2.05	2.02	1.98	1.93	1.88	1.82	1.77	1.67	1.59
463.00	1.45	1.51	1.57	1.62	1.68	1.72	1.76	1.79	1.81	1.83	1.84	1.84	1.83	1.82	1.80	1.77	1.73	1.69	1.64	1.60	1.52	1.46
542.00	1.25	1.29	1.33	1.36	1.40	1.43	1.45	1.47	1.49	1.50	1.50	1.50	1.50	1.49	1.47	1.45	1.43	1.40	1.37	1.34	1.29	1.25
642.00	1.03	1.05	1.08	1.09	1.12	1.13	1.15	1.16	1.17	1.18	1.18	1.18	1.17	1.17	1.16	1.15	1.13	1.11	1.09	1.08	1.05	1.02
742.00	0.84	0.86	0.87	0.89	0.90	0.91	0.92	0.93	0.93	0.94	0.94	0.94	0.94	0.93	0.93	0.92	0.91	0.90	0.88	0.88	0.85	0.84
842.00	0.70	0.71	0.72	0.73	0.74	0.74	0.75	0.75	0.76	0.76	0.76	0.76	0.76	0.76	0.75	0.75	0.74	0.73	0.73	0.72	0.71	0.69
942.00	0.58	0.59	0.60	0.60	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.63	0.63	0.62	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.58

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
10	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
11	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
13	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
23	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.10**	**0.10**	**0.11**	**0.12**	**0.12**	**0.13**	**0.14**	**0.14**	**0.15**	**0.16**	**0.16**	**0.17**	**0.18**	**0.18**	**0.18**	**0.18**	**0.17**	**0.17**	**0.16**	**0.15**	**0.14**	**0.12**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 8 (East Boundary)

SUMMARY OF SETTLEMENT							
Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-145.6	171.0	0.10	2	-129.8	171.0	0.10
3	-114.1	171.0	0.11	4	-100.4	171.0	0.12
5	-82.6	171.0	0.12	6	-66.8	171.0	0.13
7	-51.1	171.0	0.14	8	-35.3	171.0	0.14
9	-19.6	171.0	0.15	10	0.0	171.0	0.16
11	14.2	171.0	0.16	12	27.7	171.0	0.17
13	43.4	171.0	0.18	14	59.2	171.0	0.18
15	74.9	171.0	0.18	16	90.7	171.0	0.18
17	106.0	171.0	0.17	18	122.2	171.0	0.17
19	137.9	171.0	0.16	20	148.0	171.0	0.15
21	169.4	171.0	0.14	22	185.2	171.0	0.12

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 8 (East Boundary)

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, LBRM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 9 (33' West)

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	138.0	2	-129.8	138.0
3	-114.1	138.0	4	-100.4	138.0
5	-82.6	138.0	6	-66.8	138.0
7	-51.1	138.0	8	-35.3	138.0
9	-19.6	138.0	10	0.0	138.0
11	14.2	138.0	12	27.7	138.0
13	43.4	138.0	14	59.2	138.0
15	74.9	138.0	16	90.7	138.0
17	106.0	138.0	18	122.2	138.0
19	137.9	138.0	20	148.0	138.0
21	169.4	138.0	22	185.2	138.0

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	91508	2	15.00	18.00	91508
3	28.00	8.00	11650	4	36.00	8.00	11650
5	50.00	20.00	139212	6	70.00	20.00	139212
7	92.50	25.00	139212	8	107.00	4.00	11650
9	120.50	23.00	139212	10	149.00	34.00	139212
11	183.00	34.00	139212	12	214.50	29.00	44754
13	239.00	20.00	91866	14	264.00	30.00	91866
15	294.00	30.00	91866	16	324.00	30.00	75174
17	355.00	32.00	75174	18	386.00	30.00	90209
19	417.50	33.00	90209	20	463.00	58.00	200298
21	542.00	100.00	200298	22	642.00	100.00	200298
23	742.00	100.00	200298	24	842.00	100.00	200298
25	942.00	100.00	200298				

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 9 (33' West)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Depth (FT)	Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	0.03	0.05	0.06	0.06	0.07	0.07	0.07	0.08	0.10	0.38	3.69	6.96	7.26	7.30	7.30	7.30	7.30	7.29	7.28	7.27	7.03	3.64
70.00	0.50	0.69	0.82	0.89	0.95	0.98	1.02	1.11	1.33	2.34	4.08	5.75	6.69	6.98	7.05	7.04	6.98	6.88	6.73	6.55	5.47	3.46
92.50	1.16	1.50	1.78	1.96	2.12	2.24	2.37	2.56	2.90	3.72	4.58	5.39	6.07	6.42	6.54	6.52	6.40	6.18	5.84	5.52	4.40	3.20
107.00	1.49	1.85	2.18	2.40	2.64	2.81	2.98	3.21	3.55	4.19	4.77	5.32	5.81	6.10	6.20	6.17	6.02	5.75	5.36	5.02	4.02	3.08
120.50	1.72	2.09	2.43	2.68	2.96	3.17	3.38	3.62	3.94	4.45	4.87	5.25	5.61	5.83	5.90	5.85	5.68	5.40	5.00	4.67	3.77	3.00
149.00	2.04	2.39	2.73	3.00	3.31	3.56	3.80	4.04	4.30	4.62	4.86	5.06	5.24	5.33	5.34	5.25	5.06	4.78	4.41	4.13	3.43	2.88
183.00	2.24	2.55	2.85	3.10	3.41	3.65	3.88	4.09	4.28	4.50	4.63	4.73	4.80	4.81	4.76	4.65	4.47	4.22	3.91	3.69	3.16	2.75
214.50	2.31	2.58	2.84	3.06	3.33	3.55	3.75	3.92	4.08	4.23	4.31	4.36	4.39	4.37	4.30	4.18	4.02	3.80	3.55	3.37	2.96	2.64
239.00	2.31	2.54	2.78	2.97	3.21	3.41	3.58	3.73	3.86	3.98	4.04	4.07	4.08	4.05	3.97	3.86	3.72	3.53	3.31	3.16	2.81	2.54
264.00	2.28	2.48	2.69	2.86	3.07	3.24	3.39	3.51	3.62	3.72	3.76	3.78	3.78	3.74	3.67	3.57	3.44	3.27	3.09	2.96	2.66	2.44
294.00	2.21	2.38	2.56	2.70	2.88	3.02	3.14	3.25	3.33	3.41	3.44	3.45	3.44	3.40	3.34	3.25	3.14	3.00	2.85	2.74	2.50	2.31
324.00	2.12	2.27	2.41	2.53	2.68	2.80	2.90	2.98	3.05	3.11	3.14	3.14	3.13	3.09	3.04	2.96	2.87	2.75	2.62	2.54	2.33	2.18
355.00	2.01	2.13	2.26	2.36	2.48	2.57	2.66	2.73	2.78	2.83	2.85	2.85	2.84	2.81	2.76	2.69	2.62	2.52	2.41	2.34	2.17	2.04
386.00	1.90	2.00	2.10	2.19	2.29	2.37	2.44	2.49	2.54	2.57	2.59	2.59	2.58	2.55	2.51	2.45	2.39	2.31	2.22	2.16	2.02	1.91
417.50	1.78	1.87	1.95	2.02	2.11	2.17	2.23	2.27	2.31	2.34	2.35	2.35	2.34	2.32	2.28	2.24	2.18	2.12	2.04	1.99	1.88	1.79
463.00	1.62	1.69	1.75	1.81	1.87	1.92	1.96	2.00	2.02	2.04	2.05	2.05	2.04	2.02	2.00	1.96	1.92	1.87	1.81	1.77	1.68	1.61
542.00	1.36	1.41	1.45	1.48	1.52	1.56	1.58	1.60	1.62	1.63	1.64	1.64	1.63	1.62	1.60	1.58	1.55	1.52	1.48	1.46	1.40	1.35
642.00	1.09	1.12	1.15	1.17	1.19	1.21	1.23	1.24	1.25	1.26	1.26	1.26	1.25	1.25	1.24	1.22	1.21	1.19	1.16	1.15	1.11	1.08
742.00	0.89	0.90	0.92	0.93	0.95	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.98	0.98	0.97	0.97	0.96	0.94	0.93	0.92	0.90	0.88
842.00	0.73	0.74	0.75	0.76	0.77	0.77	0.78	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.77	0.76	0.75	0.75	0.73	0.72
942.00	0.60	0.61	0.62	0.62	0.63	0.64	0.64	0.64	0.65	0.65	0.65	0.65	0.65	0.64	0.64	0.64	0.63	0.63	0.62	0.62	0.61	0.60

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
9	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
23	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.12**	**0.14**	**0.15**	**0.15**	**0.16**	**0.17**	**0.18**	**0.19**	**0.19**	**0.21**	**0.22**	**0.23**	**0.24**	**0.24**	**0.24**	**0.24**	**0.23**	**0.22**	**0.21**	**0.20**	**0.18**	**0.15**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 9 (33' West)

SUMMARY OF SETTLEMENT							
Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-145.6	138.0	**0.12**	**2**	-129.8	138.0	**0.14**
3	-114.1	138.0	**0.15**	**4**	-100.4	138.0	**0.15**
5	-82.6	138.0	**0.16**	**6**	-66.8	138.0	**0.17**
7	-51.1	138.0	**0.18**	**8**	-35.3	138.0	**0.19**
9	-19.6	138.0	**0.19**	**10**	0.0	138.0	**0.21**
11	14.2	138.0	**0.22**	**12**	27.7	138.0	**0.23**
13	43.4	138.0	**0.24**	**14**	59.2	138.0	**0.24**
15	74.9	138.0	**0.24**	**16**	90.7	138.0	**0.24**
17	106.0	138.0	**0.23**	**18**	122.2	138.0	**0.22**
19	137.9	138.0	**0.21**	**20**	148.0	138.0	**0.20**
21	169.4	138.0	**0.18**	**22**	185.2	138.0	**0.15**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 9 (33' West)

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, LBRM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 10 (66' West)

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	105.0	2	-129.8	105.0
3	-114.1	105.0	4	-100.4	105.0
5	-82.6	105.0	6	-66.8	105.0
7	-51.1	105.0	8	-35.3	105.0
9	-19.6	105.0	10	0.0	105.0
11	14.2	105.0	12	27.7	105.0
13	43.4	105.0	14	59.2	105.0
15	74.9	105.0	16	90.7	105.0
17	106.0	105.0	18	122.2	105.0
19	137.9	105.0	20	148.0	105.0
21	169.4	105.0	22	185.2	105.0

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	91508	2	15.00	18.00	91508
3	28.00	8.00	11650	4	36.00	8.00	11650
5	50.00	20.00	139212	6	70.00	20.00	139212
7	92.50	25.00	139212	8	107.00	4.00	11650
9	120.50	23.00	139212	10	149.00	34.00	139212
11	183.00	34.00	139212	12	214.50	29.00	44754
13	239.00	20.00	91866	14	264.00	30.00	91866
15	294.00	30.00	91866	16	324.00	30.00	75174
17	355.00	32.00	75174	18	386.00	30.00	90209
19	417.50	33.00	90209	20	463.00	58.00	200298
21	542.00	100.00	200298	22	642.00	100.00	200298
23	742.00	100.00	200298	24	842.00	100.00	200298
25	942.00	100.00	200298				

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 10 (66' West)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	3.27	6.30	6.50	6.52	6.53	6.54	6.54	6.54	6.55	6.70	8.36	10.01	10.16	10.18	10.18	10.12	9.30	8.47	8.39	8.25	7.85	4.07
70.00	3.27	5.13	5.99	6.28	6.43	6.49	6.54	6.60	6.75	7.33	8.28	9.19	9.71	9.87	9.84	9.61	9.10	8.51	8.09	7.78	6.39	4.04
92.50	3.26	4.44	5.31	5.79	6.14	6.33	6.48	6.65	6.91	7.46	8.01	8.52	8.94	9.12	9.09	8.87	8.49	7.98	7.39	6.91	5.44	3.95
107.00	3.26	4.20	4.98	5.48	5.91	6.18	6.39	6.61	6.89	7.36	7.76	8.13	8.44	8.58	8.55	8.34	7.99	7.49	6.88	6.39	5.06	3.86
120.50	3.24	4.04	4.74	5.23	5.70	6.01	6.26	6.51	6.79	7.19	7.50	7.77	8.00	8.09	8.04	7.84	7.51	7.03	6.42	5.96	4.77	3.78
149.00	3.20	3.80	4.36	4.79	5.26	5.60	5.90	6.16	6.41	6.70	6.89	7.03	7.14	7.15	7.06	6.86	6.56	6.13	5.61	5.23	4.31	3.59
183.00	3.12	3.57	4.01	4.36	4.77	5.09	5.37	5.61	5.82	6.03	6.14	6.21	6.24	6.20	6.08	5.89	5.63	5.27	4.86	4.57	3.89	3.37
214.50	3.00	3.37	3.72	4.01	4.36	4.63	4.87	5.08	5.25	5.40	5.47	5.51	5.51	5.45	5.33	5.16	4.93	4.64	4.32	4.09	3.56	3.16
239.00	2.90	3.20	3.50	3.75	4.05	4.29	4.50	4.67	4.82	4.94	5.00	5.02	5.00	4.94	4.83	4.67	4.48	4.23	3.96	3.77	3.33	3.00
264.00	2.77	3.03	3.29	3.50	3.76	3.96	4.14	4.28	4.40	4.51	4.55	4.56	4.54	4.48	4.38	4.24	4.08	3.87	3.64	3.48	3.12	2.84
294.00	2.62	2.83	3.04	3.22	3.43	3.59	3.74	3.86	3.95	4.03	4.06	4.07	4.05	3.99	3.91	3.79	3.66	3.49	3.30	3.17	2.88	2.65
324.00	2.46	2.64	2.81	2.95	3.12	3.26	3.38	3.47	3.55	3.61	3.64	3.64	3.62	3.57	3.50	3.40	3.29	3.15	3.00	2.89	2.65	2.47
355.00	2.29	2.44	2.58	2.70	2.84	2.95	3.04	3.12	3.18	3.23	3.25	3.25	3.23	3.19	3.13	3.05	2.96	2.85	2.72	2.64	2.44	2.29
386.00	2.13	2.25	2.37	2.47	2.58	2.67	2.75	2.81	2.86	2.90	2.91	2.91	2.89	2.86	2.81	2.75	2.67	2.58	2.48	2.41	2.25	2.12
417.50	1.98	2.08	2.17	2.25	2.35	2.42	2.48	2.53	2.57	2.60	2.61	2.61	2.60	2.57	2.53	2.48	2.41	2.34	2.25	2.20	2.06	1.96
463.00	1.77	1.85	1.92	1.98	2.05	2.10	2.15	2.19	2.22	2.24	2.25	2.25	2.24	2.21	2.18	2.14	2.10	2.04	1.98	1.93	1.83	1.75
542.00	1.46	1.51	1.56	1.59	1.64	1.67	1.70	1.72	1.74	1.76	1.76	1.76	1.75	1.74	1.72	1.69	1.66	1.63	1.59	1.56	1.50	1.44
642.00	1.15	1.18	1.21	1.23	1.26	1.28	1.30	1.31	1.32	1.33	1.33	1.33	1.32	1.32	1.30	1.29	1.27	1.25	1.23	1.21	1.17	1.14
742.00	0.92	0.94	0.96	0.97	0.99	1.00	1.01	1.02	1.03	1.03	1.03	1.03	1.03	1.02	1.02	1.01	1.00	0.98	0.97	0.96	0.94	0.92
842.00	0.75	0.76	0.77	0.78	0.79	0.80	0.81	0.81	0.82	0.82	0.82	0.82	0.82	0.82	0.81	0.81	0.80	0.79	0.78	0.77	0.76	0.75
942.00	0.62	0.63	0.64	0.64	0.65	0.65	0.66	0.66	0.66	0.67	0.67	0.67	0.66	0.66	0.66	0.66	0.65	0.65	0.64	0.64	0.62	0.62

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 10 (66' West)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
6	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
7	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
8	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.01
9	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
10	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
12	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
23	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.17**	**0.19**	**0.21**	**0.23**	**0.24**	**0.25**	**0.26**	**0.26**	**0.27**	**0.28**	**0.29**	**0.30**	**0.30**	**0.30**	**0.30**	**0.29**	**0.28**	**0.26**	**0.25**	**0.24**	**0.21**	**0.18**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 10 (66' West)

Appendix E

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 10 (66' West)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-145.6	105.0	**0.17**	**2**	-129.8	105.0	**0.19**
3	-114.1	105.0	**0.21**	**4**	-100.4	105.0	**0.23**
5	-82.6	105.0	**0.24**	**6**	-66.8	105.0	**0.25**
7	-51.1	105.0	**0.26**	**8**	-35.3	105.0	**0.26**
9	-19.6	105.0	**0.27**	**10**	0.0	105.0	**0.28**
11	14.2	105.0	**0.29**	**12**	27.7	105.0	**0.30**
13	43.4	105.0	**0.30**	**14**	59.2	105.0	**0.30**
15	74.9	105.0	**0.30**	**16**	90.7	105.0	**0.29**
17	106.0	105.0	**0.28**	**18**	122.2	105.0	**0.26**
19	137.9	105.0	**0.25**	**20**	148.0	105.0	**0.24**
21	169.4	105.0	**0.21**	**22**	185.2	105.0	**0.18**

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, LBRM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 11 (171' West)

SUMMARY OF INPUT

Number of Loaded Areas= 9 **Number of Soil Layers=** 25 **Number of Settlement Points=** 22

Poisson's Ratio= 0.30 **Stress distribution code=** 1 **Depth of Grondwater Table=** 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	0.0	2	-129.8	0.0
3	-114.1	0.0	4	-100.4	0.0
5	-82.6	0.0	6	-66.8	0.0
7	-51.1	0.0	8	-35.3	0.0
9	-19.6	0.0	10	0.0	0.0
11	14.2	0.0	12	27.7	0.0
13	43.4	0.0	14	59.2	0.0
15	74.9	0.0	16	90.7	0.0
17	106.0	0.0	18	122.2	0.0
19	137.9	0.0	20	148.0	0.0
21	169.4	0.0	22	185.2	0.0

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	91508	2	15.00	18.00	91508
3	28.00	8.00	11650	4	36.00	8.00	11650
5	50.00	20.00	139212	6	70.00	20.00	139212
7	92.50	25.00	139212	8	107.00	4.00	11650
9	120.50	23.00	139212	10	149.00	34.00	139212
11	183.00	34.00	139212	12	214.50	29.00	44754
13	239.00	20.00	91866	14	264.00	30.00	91866
15	294.00	30.00	91866	16	324.00	30.00	75174
17	355.00	32.00	75174	18	386.00	30.00	90209
19	417.50	33.00	90209	20	463.00	58.00	200298
21	542.00	100.00	200298	22	642.00	100.00	200298
23	742.00	100.00	200298	24	842.00	100.00	200298
25	942.00	100.00	200298				

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 11 (171' West)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	6.54	12.60	12.99	13.05	13.06	13.07	13.07	13.07	13.07	13.07	13.07	13.07	13.07	13.07	13.05	12.94	11.30	9.64	9.49	9.23	8.66	4.49
70.00	6.50	10.22	11.93	12.50	12.78	12.88	12.93	12.95	12.97	12.97	12.97	12.96	12.93	12.86	12.68	12.18	11.15	10.01	9.30	8.84	7.16	4.53
92.50	6.35	8.68	10.39	11.29	11.95	12.25	12.41	12.51	12.56	12.58	12.58	12.54	12.46	12.29	11.97	11.43	10.67	9.76	8.84	8.18	6.35	4.60
107.00	6.20	8.04	9.54	10.47	11.25	11.65	11.90	12.05	12.13	12.17	12.16	12.12	12.00	11.79	11.44	10.91	10.23	9.39	8.45	7.78	6.07	4.63
120.50	6.03	7.55	8.86	9.75	10.56	11.03	11.33	11.53	11.64	11.70	11.69	11.64	11.50	11.27	10.91	10.41	9.77	8.97	8.07	7.43	5.87	4.63
149.00	5.60	6.68	7.67	8.40	9.17	9.67	10.03	10.28	10.44	10.54	10.53	10.47	10.33	10.09	9.75	9.29	8.74	8.05	7.27	6.73	5.49	4.55
183.00	5.07	5.83	6.54	7.10	7.73	8.18	8.53	8.79	8.97	9.08	9.09	9.03	8.90	8.69	8.39	8.01	7.56	7.00	6.39	5.97	5.03	4.34
214.50	4.59	5.16	5.70	6.14	6.64	7.02	7.32	7.56	7.72	7.83	7.84	7.80	7.69	7.51	7.27	6.95	6.59	6.14	5.66	5.33	4.61	4.06
239.00	4.24	4.70	5.15	5.50	5.92	6.24	6.51	6.71	6.86	6.96	6.97	6.94	6.85	6.70	6.49	6.22	5.92	5.55	5.15	4.88	4.28	3.83
264.00	3.91	4.29	4.65	4.95	5.29	5.56	5.78	5.96	6.09	6.18	6.19	6.16	6.09	5.96	5.79	5.57	5.31	5.01	4.68	4.46	3.96	3.59
294.00	3.55	3.85	4.13	4.37	4.65	4.86	5.04	5.18	5.29	5.36	5.38	5.36	5.30	5.20	5.06	4.88	4.68	4.44	4.17	4.00	3.60	3.31
324.00	3.22	3.46	3.69	3.88	4.10	4.27	4.41	4.53	4.62	4.68	4.69	4.67	4.63	4.55	4.44	4.30	4.13	3.94	3.73	3.59	3.27	3.03
355.00	2.92	3.11	3.29	3.44	3.62	3.75	3.87	3.96	4.03	4.08	4.09	4.08	4.04	3.98	3.89	3.78	3.65	3.50	3.33	3.22	2.96	2.77
386.00	2.64	2.80	2.94	3.06	3.21	3.32	3.41	3.48	3.54	3.58	3.59	3.58	3.55	3.50	3.43	3.34	3.24	3.12	2.98	2.89	2.69	2.53
417.50	2.40	2.52	2.64	2.74	2.85	2.94	3.01	3.07	3.12	3.15	3.16	3.15	3.13	3.09	3.03	2.96	2.88	2.78	2.67	2.60	2.43	2.31
463.00	2.09	2.18	2.27	2.34	2.43	2.49	2.54	2.59	2.62	2.64	2.65	2.64	2.63	2.60	2.56	2.51	2.45	2.38	2.30	2.24	2.12	2.02
542.00	1.66	1.72	1.78	1.82	1.87	1.91	1.94	1.97	1.99	2.00	2.00	2.00	1.99	1.98	1.95	1.92	1.89	1.84	1.79	1.76	1.68	1.62
642.00	1.27	1.31	1.34	1.36	1.39	1.41	1.43	1.45	1.46	1.47	1.47	1.47	1.46	1.45	1.44	1.42	1.40	1.38	1.35	1.33	1.29	1.25
742.00	1.00	1.02	1.04	1.05	1.07	1.08	1.09	1.10	1.11	1.11	1.11	1.11	1.11	1.11	1.10	1.09	1.08	1.06	1.04	1.03	1.01	0.99
842.00	0.80	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.86	0.86	0.85	0.84	0.83	0.82	0.80	0.79
942.00	0.65	0.66	0.67	0.68	0.68	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.65

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 11 (171' West)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
6	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
7	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
8	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.02	0.02
9	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
10	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01
11	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
12	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.03	0.03
13	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
15	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
16	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
17	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
23	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.25**	**0.29**	**0.32**	**0.34**	**0.36**	**0.38**	**0.39**	**0.40**	**0.40**	**0.40**	**0.40**	**0.40**	**0.40**	**0.39**	**0.38**	**0.37**	**0.35**	**0.33**	**0.30**	**0.29**	**0.25**	**0.21**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 11 (171' West)

SUMMARY OF SETTLEMENT							
Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-145.6	0.0	**0.25**	**2**	-129.8	0.0	**0.29**
3	-114.1	0.0	**0.32**	**4**	-100.4	0.0	**0.34**
5	-82.6	0.0	**0.36**	**6**	-66.8	0.0	**0.38**
7	-51.1	0.0	**0.39**	**8**	-35.3	0.0	**0.40**
9	-19.6	0.0	**0.40**	**10**	0.0	0.0	**0.40**
11	14.2	0.0	**0.40**	**12**	27.7	0.0	**0.40**
13	43.4	0.0	**0.40**	**14**	59.2	0.0	**0.39**
15	74.9	0.0	**0.38**	**16**	90.7	0.0	**0.37**
17	106.0	0.0	**0.35**	**18**	122.2	0.0	**0.33**
19	137.9	0.0	**0.30**	**20**	148.0	0.0	**0.29**
21	169.4	0.0	**0.25**	**22**	185.2	0.0	**0.21**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 11 (171' West)

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, LBRM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 12 (281.665' West)

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	-110.7	2	-129.8	-110.7
3	-114.1	-110.7	4	-100.4	-110.7
5	-82.6	-110.7	6	-66.8	-110.7
7	-51.1	-110.7	8	-35.3	-110.7
9	-19.6	-110.7	10	0.0	-110.7
11	14.2	-110.7	12	27.7	-110.7
13	43.4	-110.7	14	59.2	-110.7
15	74.9	-110.7	16	90.7	-110.7
17	106.0	-110.7	18	122.2	-110.7
19	137.9	-110.7	20	148.0	-110.7
21	169.4	-110.7	22	185.2	-110.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	91508	2	15.00	18.00	91508
3	28.00	8.00	11650	4	36.00	8.00	11650
5	50.00	20.00	139212	6	70.00	20.00	139212
7	92.50	25.00	139212	8	107.00	4.00	11650
9	120.50	23.00	139212	10	149.00	34.00	139212
11	183.00	34.00	139212	12	214.50	29.00	44754
13	239.00	20.00	91866	14	264.00	30.00	91866
15	294.00	30.00	91866	16	324.00	30.00	75174
17	355.00	32.00	75174	18	386.00	30.00	90209
19	417.50	33.00	90209	20	463.00	58.00	200298
21	542.00	100.00	200298	22	642.00	100.00	200298
23	742.00	100.00	200298	24	842.00	100.00	200298
25	942.00	100.00	200298				

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 12 (281.665' West)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	5.65	10.88	11.19	10.84	10.45	10.44	10.44	10.44	10.44	10.44	10.44	10.44	10.44	10.43	10.42	10.32	8.94	7.54	7.45	7.45	7.22	3.75
70.00	5.60	8.77	10.13	10.40	10.38	10.37	10.37	10.38	10.38	10.39	10.38	10.37	10.34	10.29	10.13	9.71	8.85	7.93	7.42	7.14	5.91	3.76
92.50	5.47	7.43	8.79	9.45	9.86	10.02	10.10	10.15	10.17	10.17	10.16	10.12	10.04	9.90	9.63	9.17	8.56	7.83	7.12	6.63	5.21	3.80
107.00	5.37	6.90	8.12	8.83	9.38	9.64	9.80	9.88	9.93	9.94	9.92	9.86	9.75	9.57	9.27	8.83	8.27	7.59	6.86	6.33	4.99	3.83
120.50	5.25	6.52	7.59	8.29	8.91	9.24	9.45	9.57	9.64	9.65	9.63	9.56	9.43	9.22	8.91	8.49	7.96	7.32	6.60	6.08	4.84	3.84
149.00	4.97	5.88	6.70	7.31	7.92	8.31	8.58	8.76	8.86	8.90	8.88	8.80	8.65	8.43	8.13	7.73	7.27	6.69	6.05	5.61	4.59	3.82
183.00	4.59	5.24	5.86	6.34	6.86	7.23	7.50	7.70	7.82	7.88	7.86	7.80	7.66	7.45	7.18	6.84	6.44	5.96	5.44	5.09	4.30	3.71
214.50	4.22	4.72	5.20	5.58	6.01	6.32	6.57	6.76	6.88	6.94	6.93	6.88	6.76	6.58	6.35	6.06	5.73	5.34	4.92	4.64	4.01	3.54
239.00	3.94	4.35	4.75	5.06	5.43	5.70	5.92	6.08	6.20	6.26	6.25	6.21	6.11	5.96	5.76	5.51	5.23	4.90	4.54	4.31	3.78	3.39
264.00	3.67	4.01	4.33	4.59	4.90	5.13	5.32	5.46	5.56	5.62	5.62	5.58	5.50	5.37	5.20	5.00	4.76	4.48	4.19	3.99	3.54	3.21
294.00	3.35	3.63	3.89	4.10	4.34	4.53	4.69	4.81	4.89	4.94	4.94	4.92	4.85	4.75	4.61	4.44	4.25	4.03	3.79	3.63	3.27	3.00
324.00	3.06	3.28	3.49	3.66	3.86	4.01	4.14	4.24	4.31	4.35	4.36	4.34	4.28	4.20	4.09	3.96	3.80	3.62	3.43	3.30	3.01	2.79
355.00	2.79	2.97	3.13	3.27	3.43	3.55	3.66	3.74	3.79	3.83	3.84	3.82	3.78	3.71	3.63	3.52	3.40	3.25	3.09	2.99	2.75	2.57
386.00	2.54	2.68	2.82	2.93	3.06	3.16	3.24	3.31	3.35	3.39	3.39	3.38	3.34	3.29	3.22	3.14	3.04	2.92	2.80	2.71	2.52	2.37
417.50	2.31	2.43	2.54	2.63	2.73	2.81	2.88	2.93	2.97	3.00	3.00	2.99	2.97	2.93	2.87	2.80	2.72	2.63	2.53	2.46	2.30	2.18
463.00	2.02	2.11	2.19	2.26	2.34	2.40	2.45	2.49	2.52	2.54	2.54	2.53	2.52	2.49	2.45	2.40	2.34	2.27	2.19	2.14	2.02	1.93
542.00	1.62	1.68	1.73	1.77	1.82	1.85	1.88	1.91	1.93	1.94	1.94	1.94	1.93	1.91	1.89	1.86	1.82	1.78	1.73	1.70	1.62	1.57
642.00	1.25	1.28	1.31	1.33	1.36	1.38	1.40	1.41	1.42	1.43	1.43	1.43	1.43	1.42	1.40	1.39	1.37	1.34	1.31	1.30	1.25	1.22
742.00	0.98	1.00	1.02	1.04	1.05	1.06	1.07	1.08	1.09	1.09	1.09	1.09	1.09	1.08	1.08	1.07	1.05	1.04	1.02	1.01	0.99	0.97
842.00	0.79	0.80	0.81	0.82	0.83	0.84	0.85	0.85	0.86	0.86	0.86	0.86	0.86	0.85	0.85	0.84	0.84	0.83	0.82	0.81	0.79	0.78
942.00	0.65	0.65	0.66	0.67	0.67	0.68	0.68	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.68	0.68	0.67	0.66	0.66	0.65	0.64

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 12 (281.665' West)

Appendix E

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
6	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
7	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
8	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.01
9	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
10	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
11	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
12	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
23	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.23**	**0.27**	**0.29**	**0.31**	**0.32**	**0.34**	**0.34**	**0.35**	**0.35**	**0.36**	**0.36**	**0.35**	**0.35**	**0.34**	**0.33**	**0.32**	**0.30**	**0.28**	**0.27**	**0.25**	**0.22**	**0.19**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 12 (281.665' West)

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 12 (281.665' West)

SUMMARY OF SETTLEMENT							
Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-145.6	-110.7	0.23	2	-129.8	-110.7	0.27
3	-114.1	-110.7	0.29	4	-100.4	-110.7	0.31
5	-82.6	-110.7	0.32	6	-66.8	-110.7	0.34
7	-51.1	-110.7	0.34	8	-35.3	-110.7	0.35
9	-19.6	-110.7	0.35	10	0.0	-110.7	0.36
11	14.2	-110.7	0.36	12	27.7	-110.7	0.35
13	43.4	-110.7	0.35	14	59.2	-110.7	0.34
15	74.9	-110.7	0.33	16	90.7	-110.7	0.32
17	106.0	-110.7	0.30	18	122.2	-110.7	0.28
19	137.9	-110.7	0.27	20	148.0	-110.7	0.25
21	169.4	-110.7	0.22	22	185.2	-110.7	0.19

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, LBRM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	-174.7	2	-129.8	-174.7
3	-114.1	-174.7	4	-100.4	-174.7
5	-82.6	-174.7	6	-66.8	-174.7
7	-51.1	-174.7	8	-35.3	-174.7
9	-19.6	-174.7	10	0.0	-174.7
11	14.2	-174.7	12	27.7	-174.7
13	43.4	-174.7	14	59.2	-174.7
15	74.9	-174.7	16	90.7	-174.7
17	106.0	-174.7	18	122.2	-174.7
19	137.9	-174.7	20	148.0	-174.7
21	169.4	-174.7	22	185.2	-174.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	91508	2	15.00	18.00	91508
3	28.00	8.00	11650	4	36.00	8.00	11650
5	50.00	20.00	139212	6	70.00	20.00	139212
7	92.50	25.00	139212	8	107.00	4.00	11650
9	120.50	23.00	139212	10	149.00	34.00	139212
11	183.00	34.00	139212	12	214.50	29.00	44754
13	239.00	20.00	91866	14	264.00	30.00	91866
15	294.00	30.00	91866	16	324.00	30.00	75174
17	355.00	32.00	75174	18	386.00	30.00	90209
19	417.50	33.00	90209	20	463.00	58.00	200298
21	542.00	100.00	200298	22	642.00	100.00	200298
23	742.00	100.00	200298	24	842.00	100.00	200298
25	942.00	100.00	200298				

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 13 (345.668' West)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	4.75	9.16	9.37	8.64	7.84	7.81	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.79	7.71	6.58	5.44	5.41	5.67	5.79	3.00
70.00	4.65	7.26	8.25	8.22	7.90	7.78	7.75	7.74	7.74	7.74	7.73	7.72	7.70	7.66	7.54	7.20	6.51	5.80	5.50	5.40	4.64	2.97
92.50	4.41	5.96	6.96	7.35	7.50	7.52	7.52	7.53	7.53	7.53	7.51	7.48	7.42	7.31	7.10	6.75	6.28	5.76	5.28	4.96	3.97	2.92
107.00	4.24	5.43	6.32	6.79	7.10	7.22	7.29	7.32	7.33	7.33	7.31	7.27	7.18	7.04	6.81	6.48	6.07	5.58	5.07	4.71	3.76	2.90
120.50	4.10	5.07	5.85	6.33	6.72	6.91	7.02	7.08	7.11	7.11	7.09	7.04	6.94	6.78	6.55	6.23	5.85	5.38	4.87	4.51	3.62	2.89
149.00	3.83	4.51	5.12	5.55	5.97	6.23	6.41	6.52	6.58	6.60	6.57	6.51	6.40	6.23	6.00	5.71	5.37	4.95	4.49	4.17	3.43	2.87
183.00	3.55	4.05	4.50	4.85	5.23	5.49	5.69	5.82	5.90	5.94	5.92	5.86	5.75	5.60	5.39	5.14	4.84	4.49	4.10	3.84	3.26	2.82
214.50	3.32	3.70	4.06	4.34	4.66	4.89	5.08	5.21	5.29	5.33	5.32	5.27	5.18	5.05	4.87	4.65	4.40	4.10	3.79	3.57	3.10	2.75
239.00	3.15	3.46	3.76	4.00	4.28	4.48	4.65	4.77	4.85	4.89	4.88	4.84	4.76	4.64	4.49	4.30	4.09	3.83	3.56	3.38	2.97	2.67
264.00	2.97	3.24	3.49	3.69	3.93	4.10	4.25	4.36	4.43	4.47	4.47	4.43	4.37	4.26	4.13	3.97	3.78	3.57	3.34	3.18	2.84	2.58
294.00	2.77	2.99	3.19	3.36	3.55	3.70	3.82	3.91	3.97	4.01	4.01	3.99	3.93	3.85	3.74	3.60	3.45	3.27	3.08	2.95	2.67	2.46
324.00	2.57	2.75	2.92	3.06	3.22	3.34	3.44	3.52	3.57	3.60	3.60	3.58	3.54	3.47	3.38	3.27	3.15	3.00	2.84	2.74	2.50	2.32
355.00	2.38	2.53	2.67	2.78	2.91	3.01	3.09	3.15	3.20	3.23	3.23	3.21	3.18	3.12	3.05	2.96	2.86	2.74	2.61	2.53	2.33	2.18
386.00	2.20	2.32	2.43	2.53	2.63	2.72	2.78	2.84	2.87	2.90	2.90	2.89	2.86	2.82	2.76	2.69	2.60	2.50	2.40	2.33	2.17	2.04
417.50	2.03	2.13	2.22	2.30	2.39	2.45	2.51	2.55	2.59	2.61	2.61	2.60	2.58	2.54	2.49	2.43	2.37	2.29	2.20	2.14	2.01	1.90
463.00	1.81	1.88	1.95	2.01	2.08	2.13	2.17	2.21	2.23	2.25	2.25	2.24	2.23	2.20	2.16	2.12	2.07	2.01	1.94	1.90	1.79	1.71
542.00	1.48	1.53	1.58	1.61	1.66	1.69	1.71	1.74	1.75	1.76	1.76	1.76	1.75	1.73	1.71	1.68	1.65	1.61	1.57	1.54	1.48	1.43
642.00	1.17	1.19	1.22	1.24	1.27	1.29	1.30	1.32	1.32	1.33	1.33	1.33	1.32	1.32	1.30	1.29	1.27	1.25	1.22	1.21	1.17	1.14
742.00	0.93	0.95	0.97	0.98	0.99	1.01	1.02	1.02	1.03	1.03	1.03	1.03	1.03	1.02	1.02	1.01	1.00	0.98	0.97	0.96	0.93	0.91
842.00	0.76	0.77	0.78	0.79	0.80	0.80	0.81	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.81	0.81	0.80	0.79	0.78	0.77	0.76	0.75
942.00	0.62	0.63	0.64	0.64	0.65	0.66	0.66	0.66	0.67	0.67	0.67	0.67	0.67	0.66	0.66	0.66	0.65	0.65	0.64	0.64	0.62	0.62

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 13 (345.668' West)

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
6	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
7	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01
9	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
10	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
11	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
23	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.19**	**0.22**	**0.24**	**0.25**	**0.26**	**0.27**	**0.27**	**0.28**	**0.28**	**0.28**	**0.28**	**0.28**	**0.28**	**0.27**	**0.26**	**0.26**	**0.24**	**0.23**	**0.21**	**0.20**	**0.18**	**0.16**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 13 (345.668' West)

SUMMARY OF SETTLEMENT							
Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-145.6	-174.7	0.19	2	-129.8	-174.7	0.22
3	-114.1	-174.7	0.24	4	-100.4	-174.7	0.25
5	-82.6	-174.7	0.26	6	-66.8	-174.7	0.27
7	-51.1	-174.7	0.27	8	-35.3	-174.7	0.28
9	-19.6	-174.7	0.28	10	0.0	-174.7	0.28
11	14.2	-174.7	0.28	12	27.7	-174.7	0.28
13	43.4	-174.7	0.28	14	59.2	-174.7	0.27
15	74.9	-174.7	0.26	16	90.7	-174.7	0.26
17	106.0	-174.7	0.24	18	122.2	-174.7	0.23
19	137.9	-174.7	0.21	20	148.0	-174.7	0.20
21	169.4	-174.7	0.18	22	185.2	-174.7	0.16

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 13 (345.668' West)

SETTLEMENT ANALYSIS FOR ELASTIC MATERIALS
Layered Method, LBRM Model

METHODOLOGY

This worksheet has been developed to calculate elastic settlement induced by foundation pressure. The soils supporting foundations are considered as layered elastic medium and the stress increment at each layer center due to a rectanglar uniformly loaded area at or below ground surface is computed by classic Boussinesq solution. The settlement for each layer is calculated using the vertical stress increment and elastic modulus of the layer, and total settlement is obtained by summing all layer settlements in the influenced zone.

Stress Increment:

The equation of Boussinesq solution to compute the stress increment under the corner of a rectanglar loaded area are shown as below. When the stress calculation point is not located under the corner of a given loaded area, superposition of rectanglar areas covering the loaded surface and stress calculation point are used to calculate the stress.

Boussinesq Solution:

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\frac{m^2+n^2+2}{m^2+n^2+1}+\sin^{-1}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1}\right)\right]$$

where q is load intensity, m=L/Z, N=B/Z, and B, L and Z are foundation width, length and stress point depth, respectively. The angle in second term in the parenthesis is less than pi /2 when m2+n2+1>m2n2, otherwise between pi /2 and pi .

Settlement Calculation:

The settlement in a given layer is calculated by an equation shown as below.

$$S_i = \Delta\sigma_{zi} H_i \frac{1-\mu_i^2}{E_i}$$

where H, E and m are layer thickness, modulus and poisson ratio, respectively.

Total Settlement:

$$S = \sum_{i=1}^{n} S_i$$

where n is number of the total layeres influenced by foundation pressures

SUMMARY OF INPUT

Number of Loaded Areas= 9 Number of Soil Layers= 25 Number of Settlement Points= 22

Poisson's Ratio= 0.30 Stress distribution code= 1 Depth of Grondwater Table= 50 FT

LOAD UNIT ID	LOAD INTENSITY KSF	EMBEDED DEPTH FT	LOAD UNIT CORNER COORDINATES (FT) X1	Y1	X2	Y2	X3	Y3	X4	Y4
1	13.1	40.0	-145.6	105.0	-100.4	105.0	-100.4	-110.7	-145.6	-110.7
2	9.5	40.0	-145.6	-110.7	-100.4	-110.7	-100.4	-238.7	-145.6	-238.7
3	13.1	40.0	-100.4	105.0	106.0	105.0	106.0	-110.7	-100.4	-110.7
4	7.8	40.0	-100.4	-110.7	106.0	-110.7	106.0	-238.7	-100.4	-238.7
5	7.3	40.0	14.2	171.0	185.2	171.0	185.2	105.0	14.2	105.0
6	9.5	40.0	106.0	105.0	148.0	105.0	148.0	-110.7	106.0	-110.7
7	9.0	40.0	148.0	105.0	185.2	105.0	185.2	-110.7	148.0	-110.7
8	5.4	40.0	106.0	-110.7	148.0	-110.7	148.0	-238.7	106.0	-238.7
9	6.0	40.0	148.0	-110.7	185.2	-110.7	185.2	-238.7	148.0	-238.7

SETTLEMENT POINT COORDINATES					
ID	X	Y	ID	X	Y
1	-145.6	-238.7	2	-129.8	-238.7
3	-114.1	-238.7	4	-100.4	-238.7
5	-82.6	-238.7	6	-66.8	-238.7
7	-51.1	-238.7	8	-35.3	-238.7
9	-19.6	-238.7	10	0.0	-238.7
11	14.2	-238.7	12	27.7	-238.7
13	43.4	-238.7	14	59.2	-238.7
15	74.9	-238.7	16	90.7	-238.7
17	106.0	-238.7	18	122.2	-238.7
19	137.9	-238.7	20	148.0	-238.7
21	169.4	-238.7	22	185.2	-238.7

LAYER COMPRESSIBILITY							
LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF	LAYER ID	DEPTH FT	THICKNESS FT	MODULUS KSF
1	3.00	6.00	91508	2	15.00	18.00	91508
3	28.00	8.00	11650	4	36.00	8.00	11650
5	50.00	20.00	139212	6	70.00	20.00	139212
7	92.50	25.00	139212	8	107.00	4.00	11650
9	120.50	23.00	139212	10	149.00	34.00	139212
11	183.00	34.00	139212	12	214.50	29.00	44754
13	239.00	20.00	91866	14	264.00	30.00	91866
15	294.00	30.00	91866	16	324.00	30.00	75174
17	355.00	32.00	75174	18	386.00	30.00	90209
19	417.50	33.00	90209	20	463.00	58.00	200298
21	542.00	100.00	200298	22	642.00	100.00	200298
23	742.00	100.00	200298	24	842.00	100.00	200298
25	942.00	100.00	200298				

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 14 (West Boundary)

CALCULATION RESULTS

Stress Distribution: Bossinesq Solution

Stress Increment Contributed by All Loaded Areas at Each Settlement Points, KSF

Depth (FT)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50.00	2.38	4.58	4.69	4.32	3.92	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.89	3.85	3.29	2.72	2.71	2.83	2.89	1.50
70.00	2.35	3.66	4.16	4.15	3.99	3.92	3.91	3.90	3.90	3.90	3.90	3.89	3.88	3.86	3.80	3.63	3.28	2.92	2.77	2.72	2.34	1.50
92.50	2.30	3.09	3.60	3.80	3.88	3.89	3.89	3.89	3.90	3.89	3.88	3.87	3.83	3.77	3.66	3.48	3.24	2.97	2.73	2.56	2.06	1.52
107.00	2.27	2.89	3.35	3.60	3.76	3.82	3.86	3.87	3.88	3.88	3.86	3.84	3.79	3.72	3.60	3.42	3.21	2.95	2.68	2.50	2.00	1.55
120.50	2.26	2.77	3.19	3.44	3.65	3.75	3.81	3.84	3.86	3.86	3.84	3.81	3.75	3.67	3.54	3.37	3.16	2.92	2.64	2.45	1.98	1.59
149.00	2.24	2.62	2.96	3.19	3.43	3.58	3.67	3.74	3.77	3.78	3.76	3.72	3.66	3.56	3.43	3.27	3.07	2.84	2.58	2.40	1.99	1.68
183.00	2.23	2.52	2.78	2.99	3.21	3.36	3.48	3.56	3.61	3.62	3.61	3.58	3.51	3.41	3.29	3.14	2.96	2.75	2.53	2.37	2.03	1.77
214.50	2.20	2.43	2.65	2.83	3.03	3.17	3.28	3.36	3.41	3.44	3.43	3.40	3.34	3.25	3.14	3.00	2.85	2.66	2.47	2.33	2.04	1.82
239.00	2.16	2.36	2.56	2.71	2.89	3.02	3.12	3.20	3.25	3.27	3.27	3.24	3.19	3.11	3.01	2.89	2.75	2.58	2.41	2.29	2.03	1.84
264.00	2.11	2.29	2.45	2.59	2.74	2.86	2.95	3.03	3.07	3.10	3.10	3.07	3.03	2.96	2.87	2.76	2.64	2.49	2.34	2.23	2.00	1.83
294.00	2.04	2.19	2.33	2.44	2.57	2.67	2.76	2.82	2.86	2.89	2.89	2.87	2.83	2.77	2.69	2.60	2.50	2.37	2.24	2.15	1.95	1.81
324.00	1.95	2.08	2.20	2.30	2.41	2.49	2.56	2.62	2.66	2.68	2.68	2.66	2.63	2.58	2.52	2.44	2.35	2.25	2.13	2.06	1.89	1.76
355.00	1.86	1.96	2.07	2.15	2.24	2.31	2.37	2.42	2.45	2.47	2.47	2.46	2.44	2.40	2.34	2.28	2.20	2.11	2.02	1.95	1.81	1.70
386.00	1.76	1.85	1.93	2.00	2.08	2.14	2.20	2.23	2.26	2.28	2.28	2.27	2.25	2.22	2.17	2.12	2.05	1.98	1.90	1.85	1.72	1.63
417.50	1.66	1.73	1.81	1.86	1.93	1.98	2.03	2.06	2.08	2.10	2.10	2.09	2.07	2.05	2.01	1.96	1.91	1.85	1.78	1.74	1.63	1.55
463.00	1.51	1.58	1.63	1.68	1.73	1.77	1.80	1.83	1.85	1.86	1.86	1.86	1.84	1.82	1.79	1.76	1.72	1.67	1.62	1.58	1.50	1.43
542.00	1.29	1.33	1.37	1.40	1.43	1.46	1.48	1.50	1.51	1.52	1.52	1.51	1.51	1.49	1.48	1.45	1.43	1.39	1.36	1.34	1.28	1.24
642.00	1.05	1.07	1.09	1.11	1.13	1.15	1.16	1.17	1.18	1.19	1.19	1.19	1.18	1.17	1.16	1.15	1.13	1.11	1.09	1.08	1.04	1.02
742.00	0.85	0.87	0.89	0.90	0.91	0.92	0.93	0.94	0.94	0.94	0.95	0.94	0.94	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.86	0.84
842.00	0.71	0.72	0.73	0.73	0.74	0.75	0.76	0.76	0.76	0.76	0.77	0.76	0.76	0.76	0.76	0.75	0.74	0.74	0.73	0.72	0.71	0.70
942.00	0.59	0.60	0.60	0.61	0.61	0.62	0.62	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.62	0.62	0.62	0.61	0.60	0.60	0.59	0.58

SETTLEMENT DISTRIBUTION (INCHES)

Settle Point Layer ID	Settlement Contributed by All Loaded Areas for Each Layer at Each Settlement Point																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
6	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
7	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
8	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
9	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
12	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
21	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
22	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
23	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.13**	**0.15**	**0.16**	**0.17**	**0.17**	**0.18**	**0.18**	**0.19**	**0.19**	**0.19**	**0.19**	**0.19**	**0.18**	**0.18**	**0.18**	**0.17**	**0.16**	**0.15**	**0.15**	**0.14**	**0.13**	**0.11**

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 14 (West Boundary)

Appendix E

Settlement Calculation, Lower Bound Estimated Rock Modulus, Line 14 (West Boundary)

SUMMARY OF SETTLEMENT

Settlement Point	X	Y	Settlement Inches	Settlement Point	X	Y	Settlement Inches
1	-145.6	-238.7	0.13	2	-129.8	-238.7	0.15
3	-114.1	-238.7	0.16	4	-100.4	-238.7	0.17
5	-82.6	-238.7	0.17	6	-66.8	-238.7	0.18
7	-51.1	-238.7	0.18	8	-35.3	-238.7	0.19
9	-19.6	-238.7	0.19	10	0.0	-238.7	0.19
11	14.2	-238.7	0.19	12	27.7	-238.7	0.19
13	43.4	-238.7	0.18	14	59.2	-238.7	0.18
15	74.9	-238.7	0.18	16	90.7	-238.7	0.17
17	106.0	-238.7	0.16	18	122.2	-238.7	0.15
19	137.9	-238.7	0.15	20	148.0	-238.7	0.14
21	169.4	-238.7	0.13	22	185.2	-238.7	0.11